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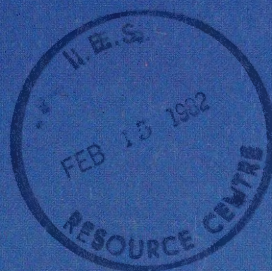
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LAKE ERIE

Tom Muir

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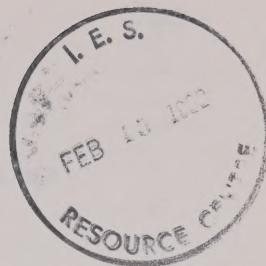
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QUALITY, ECONOMICS AND ENTROPY:
PHOSPHORUS MANAGEMENT IN
LAKE ERIE

Tom Muir

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December 1981

PREFACE

When this paper was originally conceived, it was in response to an expressed need by management oriented groups for social and economic information on phosphorus related environmental problems and remedial strategies. As the underlying research progressed, however, the basic inadequacy of conventional wisdom in such matters became increasingly obvious. In attempting to transcend these inadequacies, I was led to the discovery of a growing intellectual foundation whose development was spurred, in good part, by the failures of conventional wisdom and accepted technique. The end result, even after a great deal of truncation and sifting of relevant discussion, is a relatively lengthy document that risks collecting dust by nature of the time required to read and absorb its contents. Comments on an earlier draft suggested both lengthening and shortening the presentation, dividing it into several separate pieces, as well as the preparation of a summary document, or executive summary, containing the important conclusions. Unfortunately, the discussion herein is rather wide-ranging and contains a number of recurring themes that run throughout, making the division into several discrete parts, or the further distillation into a much smaller summary, an undertaking that, in my opinion, would be undesirable for several reasons. First, certain aspects of this paper can be treated separately at a later time if necessary. Secondly, I believe many of the concepts and ideas presented here provide such significant insights that a full reading is recommended. Thirdly, much of what is discussed is more understandable, and, in fact, obtains much of its suggestiveness, when viewed in its total context. In fact, while phosphorus management has been dealt with directly, it has been used mainly as a relevant policy issue vehicle to introduce and give perspective to a number of ideas that have a substantial scientific underpinning and are long overdue for serious debate at the policy level. For those whose personal situations dictate the virtues of brevity, I would suggest that pages 2 to 16, 68, 69, and 76 to the end contain the major arguments and intellectual debate that this paper scratches the surface of. The balance of the paper contains some interesting points sprinkled throughout, but if some elimination is desired, then I would go along with this division. Hopefully, some will be interested enough to tough out the whole paper. It was surely tough enough writing it down.

None so blind as those that will not see.

MATHEW HENRY

When our intellect does not conform to the reality of things or is deaf to the world of nature, it wanders in the illusion of dreams and pursues a phantom. Between God and ourselves stands nature.

POPE PIUS XII

INTRODUCTION

While certain problems with the water quality of the Great Lakes have been recognized for decades, it was not until the period of the late 1960's, with the completion of the IJC Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River Report (1970), that a formal identification of the eutrophication problem was made. Subsequently, intensive multidisciplinary studies have provided a framework of understanding on which to base remedial programs and the original, formal 1972 agreement between Canada and the United States on Great Lakes water quality (Agreement). Under the intent of this Agreement, commitments were to be made by both Canada and the U.S. to build and/or upgrade municipal sewage treatment systems designed to greatly reduce the loadings of phosphorus from those sources. Other programs designed to reduce the amount of phosphorus in household detergents have been implemented in various parts of the basin (Great Lakes Water Quality Board Report, 1980, page 23).

More recently, the completion of the IJC report of the Pollution From Land Use Activities Reference Group (PLUARG) and the 1978 revision and extension of the Canada-U.S. Agreement provided fresh insights into progress made in controlling the problem, and identified the dimensions of new problem areas. It appears that we still have some way to go. These new perspectives indicate that the least costly, and technologically simplest measures for reducing phosphorus loads may not be enough to achieve the objectives for Lakes Erie and Ontario as stated in the Agreement. The report of the Phosphorus Management Strategies Task Force (PMSTF) provided a comprehensive review of the methods and

data utilized to develop the Agreement objectives. The results of this report confirmed that additional measures, at higher costs, will likely be necessary.

It seems clear that we are at a kind of crossroads with respect to phosphorus management in the Great Lakes, particularly Lake Erie and to a lesser extent, Lake Ontario. Expenditure commitments made under the 1972 Agreement have not been entirely completed in the U.S. implying that new outlays for additional programs may be hard to come by. Questions have been raised concerning what will be accomplished by the commitments already made. In this regard, it does seem reasonable to ascertain as far as possible the state and realized effectiveness of present programs before committing ourselves to additional ones. However, one should not mistakenly believe that there are easy answers to these questions. From what can be gathered from the existing state of knowledge concerning lake ecosystems, it is clearly in error to expect the aquatic ecosystem quality of Lake Erie to improve in perfectly reverse order to the way in which it deteriorated. The PMSTF also recognized the need to consider phosphorus management from a much broader, holistic perspective, including the various human uses of the lake resource, as well as from a narrower water quality viewpoint. Simply put, a reasonable plan to achieve certain water quality objectives, however defined, requires some understanding of how these objectives are related to and affected by the broad spectrum of human needs and the general social well-being or quality of life available to basin inhabitants. In outlining suggested strategies for assessing social and economic perspectives, the PMSTF explicitly recognized the essential disciplinary complexity of such a task. Lake Erie does not exist in a vacuum; it is an integral part of a

much larger, living environment. Viewed as a living superorganism, or ecosystem, a lake exhibits complex and overlapping physical, chemical and biological processes with aquatic, terrestrial and atmospheric overlays, all of which are subject to constant change and evolution. Since the human mind can comprehend a phenomenon clearly only if it can represent that phenomenon by a mechanical model (Georgescu - Roegen, 1971, p. 141), these various aspects are generally separated for analytical purposes and special study. Such a separation is, however, wholly artificial. A natural ecosystem (or a man-made one for that matter) as a Whole has no seams where one can slice it into discretely distinct parts. In actuality the observable essence of nature is that of overlapping elements leaving no holes (Georgescu - Roegen, 1971, p. 47, 66, 67.). For every process and overlay, there is some of each in the other. Therefore, a full understanding of the parts requires that we look at the Whole and vice-versa. The epistemological tenet proposed by Niels Bohr and known as the Principle of Complementarity illustrates this point in stating that: "Only the totality of the phenomenon exhausts the possible information about the objects". (Georgescu - Roegen, 1971, p. 34). Also, Odum (1977, p. 1289) notes that the literature on the "new ecology" and hierarchal theory and philosophy supports the notion that as components or subsets are combined into larger functional wholes, new properties emerge that were not present or not evident at the previously lower level. Georgescu - Roegen (1971, Chapter V) provides an insightful synthesis of a number of observable regularities of fact to illustrate the essence of novelty by combination evident throughout nature, revealing its most striking forms in biological and social organisms. He observes (page 116) that combination per se contributes something that is not deducible from the properties of individual elements. The fundamental

existence of novelty and the constantly changing and evolving character of phenomenon impart an essential qualitative dimension to actuality that cannot be removed or adequately dealt with by partial perspectives and logically or mathematically based analytical methods alone.

It is therefore seen that emergent properties of ecosystems can only be more fully appreciated or even discovered through the complementary functions of perspectives based on the Whole as well as the parts. In addition, the whole of human intellectual capacity must be purposefully drawn on, including the creative, intuitive side of Mind that has formed the cognitive basis of our species throughout most of its evolution. The powerful logical and analytical capabilities of humans are not sufficient to the task by themselves and in any case form only one aspect of an essentially dualistic reasoning process in man. (Blakeslee, 1980; Sagan, 1977; Geschwind, 1979; Georgescu - Roegen, 1971). This point should not be skipped over lightly. It is the intuitive side of Mind that perceives actuality holistically, and most importantly, it alone advances knowledge creatively.

Similarly, to understand the human organism and the superorganic nature of society requires the same kind of perspective. The societal superorganism is also an extremely complex Whole characterized by intricate and overlapping social, political, institutional, psychological, biological and economizing processes, among many others, with divisional limits set rather imprecisely by the broad spectrum of

human propensities. Most importantly, all of these processes are also possessed of the primary attribute of qualitative change and are subject to evolution. It is within this amorphous, societal Whole that we organize and provide for individual and collective survival and reproduction. It is a dynamic, evolving mix of the overlapping parts that determines the various attributes that enter into what constitutes the total valuation of our existence; the quality of life. As in natural systems, the quality of life is an emergent property of the Whole, and therefore cannot be adequately evaluated or represented by any of its respective parts alone. In addition, the quality of life or social well-being available to members of society manifests itself as an immeasurable, immaterial, psychic flux; the enjoyment of life, happiness, the state of mind, which by its very nature is observably subject to qualitative change and evolution. It is therefore absolutely essential to appreciate right at the outset that no single process of the societal Whole is sufficient onto itself to represent and determine the quality of life. Furthermore, by the very nature of the relational components as inherently qualitative, changing and evolving entities there is no possibility of completely decomposing the whole scheme into arithmetic parts which are themselves devoid of change (Georgescu - Roegen, 1971, p. 60-94). In other words, the quality of life concept is not reducible to the economic process alone, nor to any single measure like money.

In view of these comments, it should not be surprising that the question of what constitutes value in the determination of the quality of life has had a long and controversial history in the development of economic and philosophical thought. From the discussion above it follows that the economic process alone can no more realistically claim an

inviolable privilege in matters of value and quality of life than physics can in matters that pertain to environmental quality. Again, each is but a part of a much larger Whole. Unfortunately, it seems to be the temper of our times that matters economic are viewed as so dominant that the societal Whole now appears to be cast in the role of serving the needs of one of its parts (the economic process) rather than economic policy serving the social order. This seemingly upside-down relationship is in great measure explainable when one examines the vast gulf that exists between the actuality of the economic process and the representation of that process as promulgated by mainstream economic science. Georgescu - Roegen (1971), Rifkin (1980) and Stanfield (1979) present forceful arguments critical of the utterly mechanistic, ahistorical and static epistemology of standard economics. Such a representation of the economic process has no room for natural resources in its framework; therefore they are almost completely ignored. One would hardly be advised then to impute to such a framework the only valid claim to the representation and determination of the value of natural resources. The standard theory also views the economic process as neither inducing any qualitative change in its environment nor being affected by such change. It is viewed as a self-sustaining, circular affair in which the continuous inflow of natural resources from the environment and the continuous outflow of waste into the environment are practically ignored. That such things are patently contrafactual is obvious and should need no elaboration. It therefore appears equally obvious that the valuation of alternative environmental quality states simply cannot be done solely within a framework that denies the existence of such states as an attribute of economic activity.

In actuality, the economic process is a partial process of the societal Whole, the primary objective of which is the self-preservation of the human species through the satisfaction of some basic material needs. It is in fact a history-making, evolving and constrained interaction with a limited material environment that transforms accessible matter and energy into essentially valueless waste. From a thermodynamic viewpoint, matter-energy enters the economic process in a state of low entropy and leaves it in a state of high entropy. It is this entropic transformation process that forms the taproot of economic scarcity and the problems of natural resource depletion and pollution (Georgescu - Roegen, 1976; 1971). It is also a process that can only be slowed down, never reversed or even stopped, since all life and the industrial artifacts of the societal Whole are inextricably bound up in a continuous struggle for the low entropy necessary to survive and reproduce. It is therefore seen that value lies in low entropy and is first and foremost identified with that which furthers the survival and development of the species. Standard economics, however, identifies value with a single notion, price, and thereby argues that the reduction of everything to money provides an objective representation of the problem of economic scarcity and choice. Again, this totally ignores the general absence of natural resources in the standard economics framework and conceals the observable fact that in the real world things that are absolute biological requirements and indispensable for the survival of humankind very often have no exchange value or price at all. The standard economic view is therefore patently inept since by focusing solely on money and prices as representing value, it fails to see the

point just referred to; that things can have economic value but no price, however, nothing can have a price without having economic value, and to have economic value something must have low entropy.

The social and economic perspectives to be presented here will reflect and utilize the arguments made above. Where possible, those considerations that are amenable to some level of quantification in a common metric, money, will be presented as such. It is essential, however, that such standard monetary measures be viewed in the discussed perspective and recognized as being nothing more than convenient quantifications of a limited subset of the attributes of the societal Whole that enter into the determination of the quality of life. Where possible, the various uses of the lake resource that have readily available monetary valuations will be identified and related to hypotheses concerning how these money values might be affected by eutrophication. In some cases monetary measures are readily available because the use involves goods and services that can be "possessed" and therefore have prices generated by the existence of markets. Even in such cases, we do not get an objective measure of value because the theoretical foundation on which the market mechanism of resource allocation rests is loaded with value judgements and ideology as will be discussed later. Significantly, the greatest source of quality of life benefits from improved water quality seems to come from enhanced opportunities for water - based outdoor recreation. Recreation activities do not have clearly defined markets, however, so price signals indicating monetary valuation are absent. In this case it was necessary to resort to surveys of user activity and intuitively based estimates of monetary value attached to such activity in order to provide some

perspective and relation to the other aspects presented. From an overall viewpoint the discussion in these areas will serve to clarify the inherent complexity and difficulty involved in the valuation of environmental quality. Even the parochial realm of the standard monetary measure will be seen to face overwhelming theoretical, empirical and practical difficulties, most of which are associated with the holistic, qualitative and evolving nature of actuality discussed above.

From another perspective, phosphorus management programs involve the use of real resources. The policy problem is to find a mix of strategies that minimizes this use and at the same time results in water quality improvements with space and time coordinates that maximize the enhancement of uses of most value to the sustenance of society. In this respect it is essential to recall the above discussion and recognize that perhaps the most significant valuations involve a water quality - quality of life experience that is simply irreducible to a monetary measure commensurate with a market determined cost of management. One must therefore be prepared to approach the question of phosphorus management (or any aspect of environmental conservation) without rigidly held views concerning the need to demonstrate that a given program yield at least a measured dollars worth of use enhancement for every dollar spent. Such a view is derived directly from the uncritical acceptance of benefit-cost techniques and their application in areas where they are inadequate and often irrelevant. These points will be examined in more detail below.

Throughout what follows, an attempt will be made to relate to the above discussion as much as possible within bounds of limited space. Despite being our focus of discussion here, phosphorus management cannot

be effectively viewed in isolation from the overall management of the entire Great Lakes ecosystem, both natural and human. To provide some linkage to the existing framework for developing strategic plans, this paper will use the objectives as stated in the 1978 Agreement as a focal point for evaluative purposes. In addition, the suggested conceptual framework for assessing social and economic impacts together with the insights contained in the PMSTF report will be used to organize this investigation along already developed lines. Finally, to narrow the context down to manageable proportions discussion will be limited to the Lake Erie basin, though much of what will be presented is more widely applicable.

I PHOSPHORUS MANAGEMENT - WATER QUALITY - WATER USE LINKAGES

The PMSTF recognized the need for a systematic examination of the linkages between loadings reductions, water quality and water use. The recommendation that a staged approach to phosphorus management be taken is based in good measure on the uncertainty of our knowledge concerning the loadings - water quality relationship. There just are no simple proportional relationships between phosphorus loadings and water quality. Natural variability, both spatially and temporally, and intricate webs of causality represent formidable barriers to an understanding of the processes at work sufficient for definitive statements about policy impacts on water quality. Georgescu - Roegen (1971, p. 95-113) provides some interesting insights into the nature of this problem. Proportional laws, like Newton's Laws for example, are the inevitable consequence of an immediate connection (not a relation obtained by telescoping a chain of other laws) between variables that are all free from any qualitative variation; they are all cardinal variables. In contrast, commonly used measures of water quality - secchi depth, trophic status and the like - are nothing more than intelligent ways to characterize qualitative attributes using quantifiable variables; they are in essence quantified qualities. Laws involving quantified qualities are not expressed by proportional or linear formula. In fact, the general procedure of quantifying a qualitative attribute does not change the nature of the attribute itself nor does it destroy the quality ingredient of the phenomena involving such an attribute. In such cases the qualitative residual that remains is hidden in the purely numerical formula in a non-linear form. Moreover, most quality related phenomena have a sort of climax, followed by a rapid breakdown. Linear functions

cannot possibly represent such non-monotonic variation. Furthermore, the non-linearity enters not only through the variables, but also through the coefficients of the function. Such observations merit careful consideration as they put a lie to the dogma that all of the elements in nature are reducible to precise, finite and reproducible laws. (Georgescu - Roegen, 1971, p. 93). Further aggravating the viability of definitive loadings - water quality relationships is the fact that while the numerical representation of such a phenomenon, because of its essentially mechanical origins, may appear on paper to be perfectly reversible, the laws governing reversal in actuality might be totally different. At bottom then, we must realize that in the examination of phenomena involving Change, Quality, Evolution, and/or complex holistic processes, there is a definite limit to what we can do with numbers and deduction.

The linkages between water quality and water use exhibit the same basic features that circumscribe the extent to which numerical formulae are viable. Freeman (1979) presents a thorough review of the standard theoretical and empirical literature, and concludes that measuring effects, assigning values, and estimating benefits is a formidable task, with certain key aspects lying outside the realm of economics. While it is straightforward to identify formally the potentially useful techniques, and the data to collect, actually carrying out the analysis is another matter altogether. In fact, these difficulties refer only to the economic aspects of the problem. In some cases, noneconomic data - for example, dose-response (loadings-quality) functions - are required before economic analysis can even begin. In light of these difficulties it is not possible to present a formalized

treatment of water quality - water use interactions. Instead, the following discussion will consider the major water uses from a flexible and pragmatic perspective with the ultimate intent of formulating strategic guidelines that are ecologically sound and represent an economic use of management resources.

Water Quality Objectives

The 1978 Agreement between Canada and the United States specified the following specific goals for Lake Erie:

- (a) Restoration of year-round aerobic conditions in the bottom waters of the Central Basin; and
- (b) Substantial reduction in the present levels of algal biomass to a level below that of a nuisance condition.

There have been a number of discussions concerning the viability and/or the appropriateness of these goals and the programs suggested for their achievement (Wagner and Gregor, 1980; Lee and Jones, 1979; Phosphorus Management Strategies Task Force, 1980; Johnson, 1980; Charlton, 1980). There is also room for discussing the possibility of objectives based not just on specific species or factors, but also on more functional and integrative properties that might relate to the specific ones. Since the questions and decisions concerning phosphorus management clearly involve the ecosystem level, more holistic approaches that include interactive, integrative and emergent properties might provide useful objectives that

relate to real world concerns of people (Odum, 1977, p. 1291-92). Rather than continue this debate as a separate issue, it is felt that for the purposes of this examination specific goals and strategies might become more understandable and meaningful when discussed within the context of the major uses that may be affected. As Johnson (1980) notes, the goals as specified in the 1978 Agreement are not really goals at all, they are means. He also notes that there is no provision in the Agreement to assess societal goals as a basis for remedial strategies. This confusion of means with ends is quite common and is often the result of piecemeal approaches to policy and fragmented institutional responsibility. Carefully considered, the process of choosing between alternative means, often incompatible, with no reference whatever to socially relevant ends, is nonsense (Winch, 1971, p. 199). This should not be taken lightly as idealistic. Rational policy discussion can only occur in the context of relating some appropriate means to the achievement of some objective. Since the relationships between means and ends and the designation of socially appropriate ends themselves are constantly changing and evolving, policy tools may be misused or perverse if we only focus on the achievement of means. Analysis is only effectively utilized in selecting appropriate means to achieve a given end. Objectives are the product of value judgements; which in turn are hopefully expressions of holistic, intuitive and creative intellectual activity. They may be, however, expressions of will, the product of some deeply held conviction, prejudice or self-interest. It is therefore advisable to carefully develop and/or re-examine objectives with a mind to ensure that they are thoughtfully based, and not willful.

It should be noted that the above discussion is not meant to be a broadside condemnation of the phosphorus objectives contained in the Agreement. They were derived for a purpose and constrained by the context of an international agreement. The debate arises because they were framed within a limited perspective. Simply put, they lack direct social relevance, and particularly, holistic context, as Johnson (1980) points out; and as we will see later, managing water quality alone is an inadequate tool to protect aquatic resources.

II MAJOR USES OF THE LAKE RESOURCE AND GENERALIZED IMPACT OF EUTROPHICATION

The following discussion will be framed around the categories of use suggested by the PMSTF. The material presented will draw mainly on previous considerations, with emphasis on points that are important to the evolution of our ideas concerning a viable and effective phosphorus control strategy.

Municipal Water Supplies (Potable Water)

There have been a number of studies of the impact of eutrophication on the operation of municipal water treatment plants. From a purely technical viewpoint, the impacts are fairly well understood and are related to the presence of excessive numbers of aquatic plants, although algae are of primary concern in terms of water supply problems (Task Group 2610P Report, 1966). These problems can be numerous: including tastes and odours; clogging of filters; colour and turbidity; chlorine demand; growth in pipes, cooling towers and on reservoir walls;

corrosion; variable pH and hardness; floating scum; blockage of intake screens; and toxicity. For the Great Lakes in particular, the major problems caused by algae include shortened filter runs; tastes and odours, and occasional clogging of intake screens. Sudar (1978) noted that high levels of algae require that the water be treated by coagulation and sedimentation prior to filtration. Alternatively, the installation of microstrainers at Dunnville in the eastern basin, and at the Union Water Supply in the western basin was carried out, at least in part, to remove algae from the raw water. For odour problems, the use of carbon or other substances that absorb the odours is possible. At sufficiently high concentrations filter runs can be shortened and backwash water requirements, as a proportion of total treated water, can increase substantially.

While there have been reported problems in the Lake Erie basin, as in other parts of the overall Great Lakes system, they exhibit the same qualitative variability and complexity common to natural ecosystems. Specifically, time, place, algal type, treatment plant, and operational practice produce situations that vary - depending on the combination. Unfortunately, there is very little knowledge that can be generalized so as to provide a systematic overview that can be exploited for evaluation purposes. Sudar (1978) compared the Dunnville and Union Water Supply plants, both of which have the same treatment process but different amounts of algae in their raw water. The Dunnville plant had the lower average treatment costs and they rose when algal levels rose. However, the Union plant exhibited increasing costs when algal levels

declined, the exact opposite of what one would normally expect. This is simply an observation of related data, and no explanation as to why this occurred is possible from the data, or available from other plant sources.

Welch (1978) reported on problems in the Cleveland, Ohio area of Lake Erie associated with taste and odour, and filter clogging. It was noted that the real cost of treatment per million gallons doubled from \$4.50 to \$9.00 from 1968 to 1975. Throughout this review, it was clear that the increased algae growth characteristic of eutrophication can and does present significant problems, leading to increased costs due to chemical requirements, filter cleaning, and decreased water volumes for consumer use. The major shortcoming of these observations is the difficulty, or even intractability, of estimating the costs associated with these problems in a form that can be extrapolated over time, space, and level of water quality. Literature searches did not reveal any such systematic analyses. Within my work group, efforts are being made to evaluate the possibility of systematizing the water quality - treatment method/cost relationship. Preliminary results indicate that the issue is too complex, and contains too many variables to allow the estimation of a broadly useable analytical representation. These general observations are consistent with the recognized problems that statistical methods have with data that exhibits extremely wide variation and with multicollinearity among candidate explanatory variables. In any case, one can fiddle with the data and produce a fitted curve, but that doesn't make it a law that can be extrapolated all over the place. It is more useful to recall our earlier discussion and recognize this situation as a real world reflection of the limits of analytical technique.

In an IJC report entitled Cladophora in the Great Lakes (1975), it was reported that the alga, Cladophora, did not create a major problem for municipal water supplies in Ontario with the exception of isolated incidents. It was reported that intakes are designed to draw water from as deep and as close to the bottom as is practical. Welch (1978) also reported this design point in noting that intakes can be designed or situated in areas to avoid the problems associated with eutrophic waters. This consideration may mask or eliminate the relevant costs of water treatment. Again, a lack of generality makes it impossible to estimate the costs associated with intake modifications.

The Montreal Engineering Company Limited (1974) study examined a broad range of activities potentially affected by water pollution. In their examination they sent a questionnaire survey to all municipalities in Canada with over 10,000 population, except those indicating they employed only chlorination and those drawing groundwater. It was assumed that municipalities would employ chlorination irrespective of man-made pollution. This begs the question of why chlorination is used, but we will not concern ourselves with that here. For Ontario as a whole, 18 plants or 28.5 percent of the total, reported further treatment for so-called man-made pollution. Those plants drawing from Lake Erie were Elgin Area, Leamington and Port Colborne. Under the assumptions used in the analysis, the following costs of man-made pollution were estimated in 1972 dollars with approximate 1979 values in brackets:

TABLE 1

	Capital Costs (\$000/yr)		Operating Costs (\$000/yr)	
Elgin Area	145	(257)*	105	(192)**
Leamington	36	(64)*	90	(164)**
Port Colborne	54	(96)*	90	(164)**
TOTAL	235	(417)	285	(520)

* adjusted by non-residential construction price index.

** adjusted by consumer price index (all items).

Source: Economic Damages Resulting From Water Pollution. Montreal
Engineering Company Limited. 1974

Capital costs are those relating to technology additional to chlorination and are replacement costs in 1972 (1979) dollars, not necessarily what the municipality is actually paying. Also, these capital costs are 'sunk' in the existing plant and would not be recoverable even if the sources of pollution were removed. Further, these cost estimates are based on an interest rate of 6 percent, which is unrealistic given todays financial reality. Approximate adjustments would probably double these costs. From our perspective these costs are indicative of what would be involved in future water treatment capacity increases using the same technologies, design, and operating criteria. Unfortunately, these estimates are imprecise because it is not possible to assign them to a particular problem. The report states that these treatments are usually installed to remove bacterial pollution above certain levels or high levels of suspended solids. Eutrophication and algae are not mentioned explicitly for these Lake Erie plants. An activated carbon process installed at Elgin Area indicates possible algae related odour problems,

however, this process is also important for organic toxics. In fact, algae per se was mentioned explicitly in only a few instances for the whole cross-Canada survey. Other caveats contained in the report detract from the usefulness of these costs as indicators of the eutrophication process.

Sudar (1978) concluded her discussion with the comment that water treatment costs for selected Ontario treatment plants do not indicate that eutrophication has been a major ongoing determinant of those costs. She further notes that this might be due to the observation that significant costs, as incurred by other communities, are generally associated with extremely high concentration levels. As a further ambiguity, the Lake Huron Water Supply System, is the only plant in Ontario severely troubled by algae. Lake Huron is supposedly oligotrophic. So once again we come face to face with novelty by combination and the infinite variety of nature. It cannot be generally explained by deduction and logic.

From an overall perspective we can make the following observations:

- (1) Over the range of algae concentrations experienced on Lake Erie, it is difficult, if not impossible, to state precisely what eutrophication alone involves in additional water treatment costs. There have been particular events, mostly in the U.S., where algae have caused significant problems, however, these are more random than systematic in occurrence. More explicit surveys of operators and

municipal officials might elicit more precise responses. Again, however, the qualitative, changing nature of the problem would likely elude complete characterization suitable for policy purposes.

(2) Of particular importance to the development of an overall strategic plan, such water treatment problems as do occur are restricted to the near-shore zone, and might indicate water quality different from a whole lake perspective.

(3) Despite not being able to make precise evaluations, one can still draw certain insights from the available information. Clearly, at suitably high concentrations algae can present significant problems. In these cases, engineering solutions involving intake location and design might be possible. If so, the extra costs involved could be used as one indicator of eutrophication damages.

This intake relocation, while avoiding the clogged screens possibility, might not solve the shortened filter runs problem. If filter clogging occurred on a regular basis, substantial cost increases might occur as the treatment plant would run at less than design efficiency and, therefore, overall capacity. For example, Sudar (1978) reported that backwash water requirements in the 20 percent to 50 percent range of total treated water have been reported due to algae, as compared to normal design requirements of 5 percent. Given the relevant Lake Erie capital cost estimates from the Montreal Engineering Study, this might

involve, for a 20 percent efficiency loss, annualized costs of about 140,000 dollars, based on 1979 price levels and a 10 percent rate of interest. These costs would be essentially wasted. This assumes of course, that municipalities would ultimately adjust their plant size to provide the same relative amount of reliable capacity. This adjustment would not be instantaneously necessary if sufficient surplus capacity existed, however, the time horizon for capacity expansion would be shortened. Put another way, whether adjustments are actually carried out or not, some dead loss has occurred since actual reliable capacity is now less (20 percent in this example) than that originally planned.

The water quality of Lake Erie has other social implications that are not directly quantifiable in dollar terms but have longer run effects that might lead to real economic costs in the future. Sudar (1978) reported that a study of urban water supply alternatives in the Grand River Basin found that people preferred water that was least contaminated by man. This perceived quality was a more decisive factor in the decision process than was cost. It is difficult to imagine any argument concerning the absolute necessity for safe, potable water that wouldn't seem trite or obvious. If our social and economic system can't provide this most essential commodity, then it seems reasonable to seriously question its long run viability. Since the public has a negative perception of Lake Erie, extra costs are being incurred or considered by the municipalities of Kitchener-Waterloo, Guelph, and Brantford. Lake Huron is equally as favoured as Lake Erie by Brantford residents despite being 50 miles farther away. For these three municipalities, Lake Erie is by far the most economic alternative, however, because of water quality problems other sources are seriously

considered or even chosen. For example, the city of London built a pipeline to Lake Huron to satisfy its needs for adequate water. These observations are clear examples of the way in which life enjoyment or quality of life are not related only to money. In these cases the public is letting it be known that in matters of drinking water, standard economic criteria, like efficiency, count for very little. In this example scarcity relates to publicly acceptable water, not money. An important implication of this goes beyond drinking water. Such strongly held perceptions very likely manifest themselves in other ways related to recreational use and property ownership.

For those who suggest that treatment technology provides the answer, these specific examples seem to indicate that such views and attitudes are just not adequate. The technological approach overlooks the most elementary fact that biological man has an essential existential need for uncontaminated potable water. The economic man of standard economic theory is an analytical fiction that inhabits an equally fictional world that is tasteless, odourless and colourless. Only in such a quality-free world could the resource allocation problem be reduced to the so-called rationality of least-cost criteria. In the light of the present real-world example, it is seen that the removal of the uncertainty associated with perceptions of Lake Erie water quality took on a greater significance than money. This absolute primacy of biological man over economic man in matters of existential import must be an essential part of any environmental policy framework. Such truly significant dimensions of societal choice cannot be addressed solely within the mechanical world of standard economics.

Industrial Water Supplies (Direct Users)

The impacts of algae on industrial users exhibit the same variability and isolated nature as those evidenced in our discussion of drinking water supplies. The IJC (1975) reported that most industrial water intakes have been designed to minimize such problems. While algae contamination was not the only consideration in such decisions, it was undoubtedly a factor. Welch (1978) noted that reports on the impact of eutrophication on industrial water supplies are uncommon. The Montreal Engineering Study concluded that damages to industrial users are fairly minor across Canada. In general, plants that employ treatment do so primarily because of natural variations in water quality. The location decision is based primarily on available quantities of water and not on quality considerations. Where water quality is of genuine concern, such as in the food and beverage industry, it was felt that characterization of possible problems could parallel that of the municipal treatment sector. The Montreal Engineering Study very crudely estimated that damages in Ontario as a whole might range between 200,000 and 1 million (1979) dollars per year. This would depend on the proportion of water requirements met through in-plant treatment vis-a-vis purchases from municipal facilities. The share of these crude cost estimates that would accrue to firms located on Lake Erie would be pure guesswork without a specific survey to find out. For the amounts involved, this does not seem an advisable course of action.

Firms that require boiler and feed water have on occasion faced problems caused by phytoplankton related interference with the ion exchange process of demineralization. The costs involved here are unknown.

In summary, there doesn't seem to be a real problem involved with industrial water use at present levels of algae concentration. To identify accurately the possible costs that are involved would require industrial surveys far beyond the scope of this exercise, and would not likely yield useful information worthy of the cost. It should be kept in mind though that suitably high concentrations maintained over long periods might present a different situation. The most significant observation we can make is that where problems can or do occur is in the near-shore zone.

Electric Power Generation

Kelso and Milburn (1979) reported that there are 16 existing and 2 proposed thermal electric generating stations on Lake Erie. Of these, only one existing plant is on the Canadian side of Lake Erie proper, situated at Nanticoke. The general problem potential lies in the fouling of water intake screens located at the surface of the lake. The Ontario Hydro report on Aquatic Weed Growth (1967), done during the design phase of the Nanticoke station, suggested that aquatic weeds and algae could present fouling problems at the intake and in the trash rack and revolving screens. Conversations with Ontario Hydro officials involved in the final design work of the plant revealed that problems associated with ice formation and vortexing at the intake led to the decision to submerge it deeply. Weeds and algae were not considered to be problem factors.

The IJC (1975), Welch (1978) and Sudar (1978), all reported on algae related problems at Lakeview, Pickering and Saunders generating plants on Lake Ontario. Again, the problem was observed to be infrequent in occurrence, but possessing potentially serious and costly implications. It was not possible to isolate solely algae related costs on an analytically useful basis. It was also noted that submersion of intakes is often related to the presence of eutrophication related phenomena, however, the evidence on this point is contradictory, and no separable or clearly defineable relationship or cost is available.

In summary, available information suggests that symptoms of eutrophication have not presented any problems to the one generating station on Lake Erie.

Property Values

Studies aimed at estimating the effect of environmental quality on property values have a controversial history in the literature. The basic assumption underlying these studies is that environmental quality differences tend to be capitalized in land values. On the face of it, this seems to be a plausible assumption, however, the theoretical and empirical problems inherent in determining the specific functional relationship and the values of the underlying parameters are legion.

Freeman (1979) argues that the conditions under which the capitalized value of environmental benefits (costs) would be fully reflected in property value changes over time (time series analysis), or property value differences (cross section analysis) are so restrictive

that measures of such changes/differences are not likely to be useful as measures of benefits (costs). For broad policy decisions, he feels that order-of-magnitude or lower bound estimates may be valuable to decision-makers. This makes sense since it seems implausible that pollution would have no impact whatever on property values, however, it might have to be relatively severe before noticeable effects are evident.

Maler (1977) discusses the theoretical background of the use of property values in estimating damage functions. He concludes that the assumptions necessary to provide the foundation for a general equilibrium model in which environmental quality differences are capitalized into land rents and/or values are hardly realistic. While the existence of property value differentials due to water quality differences is intuitively plausible, a formal model drawing on accepted theory is necessary for the specification of the empirical testing equations. In the present case, to completely formalize the hypothesis you almost have to assume away the reality of the property market. Maler concludes; "...that the study of property values cannot give viable estimates of the marginal willingness to pay for environmental quality." (page 355)

Both Freeman and Maler go on to indicate that severe empirical data and econometric difficulties compound the theoretical problem. Thus even casual empiricism runs into enormous difficulties in trying to extract the proportion of property value change/difference associated only with the water quality variable. For example, what water quality variable do you use and how do you account for the many other attributes

that go into the determination of the market price of a piece of property? Unfortunately, these points and many others have simply not been solved in the many empirical studies carried out on this subject.

Sudar (1980) reviewed several of the studies done on the relationship between water quality and shore property values. Dornbusch et al, (1975), estimated a range of increases in real property values of from 4 percent to about 17 percent, due to water quality improvements. In another study, Dornbusch and Barrager (1973) derived water quality induced property value increases of 4.2 to 8.2 percent using econometric techniques. Further estimates developed from interviews of property owners indicated large property value increases (24 percent), in one area, when owners exhibited consensus opinions that water quality had improved. Ormerod (1970) examined recreational property values along the Lake Erie shoreline from Port Dover to Fort Erie. This was a comparison of standardized prices using simple statistical tests, and concluded that property fronted with algae averaged 80 to 85 percent of the value of property with no algae problem.

All of these studies suffer more or less from the points raised by Freeman and Maler. All lack any formal justification in theory, and the testing hypotheses appear to be seriously misspecified. The property market is simply too complicated for the existence of a simple proportional relationship between property values and environmental quality.

Sudar (1980) encountered the same problems in her analysis. To provide some further insights into the difficulties involved in the sometimes inexplicable, counter-intuitive nature of the water quality-property value relationship, properties on the highly eutrophic Bay of Quinte were compared to nearby properties fronting on mesotrophic Lake Ontario to see if there were any significant differences in market valuation. It was concluded that the two study areas have statistically significant differences in the per foot valuation of shore property, (several measures were used) but the higher valued properties were located on the Bay of Quinte where the water is most eutrophic. Possible reasons for this result are discussed in the paper.

From our perspective, it should be perfectly clear that there are such a wide range of factors that affect prices that presently available methods are simply incapable of satisfactorily separating the individual effects. In any case, over time such factors would likely change in their relationship to price. Remember, we are dealing with the dynamic, changing world of reality, and as you will recall, we have already discussed the essential impossibility of reducing this world to a mechanical model. Perhaps a most significant source of such intractability appears explicable when one realizes that shoreline properties are not homogeneous clumps of an identical commodity that can be added or subtracted in any really meaningful way. Beyond the purely conceptual definition as a quantity of property, each exists as a distinct entity, possessing purely qualitative attributes distinguishing it from the rest. The concept of average price in this context requires that we add items together that are really not subsumable because they do not relate to the same physical entity. Since subsumption in this case

makes no sense, it is no wonder that some of the results also seem to make no sense. It's like adding the price of apples and the price of pears; what meaningful average emerges?

Possibly the biggest problem with restricting analyses such as the above within a formal, seemingly rigorous framework is that while the technique appears elegant, the results can very well be spurious. Every econometrician knows that all statistical inferences and tests are based on certain assumptions. The entire edifice of statistical theory rests on the general assumption that any sample is randomly drawn from the parent population. In general, it is usually assumed that all economic data fulfill this condition as it is most often not possible to precisely identify the parent population. It doesn't take too much thinking on the matter to realize that property value studies would face serious difficulties in this matter. For example, what reason could be given for treating all properties along a given reach of shoreline that were sold during a specified period as a random sample? Another assumption that is generally not met in social science statistical studies requires that the parent population be normal. Unless this assumption is satisfied, the standard goodness-of-fit measures used to support the reliability of the statistical model are not valid. The available literature is not too encouraging of the expectation that economic data are normally distributed (Georgescu - Roegen, 1966). Possibly most condemning of such casual statistical practice is the confusion of the regression line with some law between the theoretical values of the variables. In fact, to be a law, a formula must not only fit the available observations, it must

also fit all other observations. Unfortunately, the evolving nature of most economic phenomena preclude the possibility of such extrapolations beyond the fitted observations. It follows then that one should be more critical and skeptical as regards the acceptance of fitted curves as significant representations of quantitative laws.

From an overall viewpoint then, we are likely to be presented with estimates of damages that are assumed to possess a precision and accuracy that is not warranted. Even if we abstract from the above critique and accept such damage estimates as merely reflecting correlations for a given sample, population and time period, caution is still warranted. The sampling variation generally associated with property value studies is usually significantly large, thus imparting a relatively large margin of sampling error to the empirical results. Problematically, these margins are most often ignored and the point estimates, or mean values, are looked at as the final result and given a credibility that is often not justified.

Once these analytical problems are appreciated it appears that it might be just as informative to take a synthetic overview of the situation, and using available data simply posit various hypotheses concerning possible property value losses due to eutrophication related problems. This will require a little imagination and sensitivity to the situation, however, this is necessary if we are to get out of the analytical box we are in. It also exposes us to valid criticisms of hypocrisy. Nonetheless, I proceed on the basis of a desire to provide an illustrative example of an intuitively plausible line of reasoning with no illusions of analytical rigour or validity.

With this in mind, it might be useful to examine the Lake Erie shoreline with the idea of "eye-balling" intuitively plausible valuation losses that are consistent with the gross value of potentially affected properties and previous estimates of the range of possible losses.

The north-east shoreline examined by Ormerod (1970) appears particularly suited as he noted that this area has algae problems that are above average for the Canadian side of Lake Erie. Drawing on data from the Canada-Ontario Shore Damage Survey (1975) and other sources reveals the following relevant land-use and value information for the reach bounded by Haldimand-Norfolk and Niagara counties.

TABLE 2

Residential Shoreland Use and Value
(In metres and as a percent of private shore)

COUNTY	RES PERM	RES SEAS	TOTAL	VALUE(1973\$) (per metre of total)	VALUE(1979\$)* (per metre of total)
Niagara (L.Erie)	7,200 (5.4%)	30,000 (59%)	50,000	747	1,307
Haldimand- Norfolk	10,440 (5.4%)	94,530 (49%)	193,730	216	378

* adjusted by residential building construction price index.
Source: Canada - Ontario Shore Damage Survey. 1975.

The value per metre data represent all uses and are significantly different for basically two reasons. The Niagara sample contains a significant agricultural, vacant, and other component, all lower valued. Additionally, the Haldimand-Norfolk data are based on property assessments and not market prices as used in the Niagara data. Unfortunately, market data for each specific use were not available, but for illustrative purposes these data will suffice. Finally, concentrating on residential properties alone entails the implicit assumption that other shoreline uses (excepting wetlands) such as agricultural and industrial, are not sensitive to water quality. This appears reasonable and is consistent with most published thinking on the matter.

Since the noted caveats impart a consistent downward bias to the value data relative to the 'true' worth of residential use, this information yields a lower bound estimate of the total 1979 dollar valuation of residential properties as follows: Niagara, approximately \$49 million; and Haldimand-Norfolk, about \$40 million; for a total of \$89 million.

Given these values, we need to develop a base from which to derive plausible hypotheses concerning value losses due to water quality problems. Armstrong and Denuyl (1977) observed that shoreline lots cost more than similar lots inland because of various values provided by the lakeside location. These values are chiefly aesthetic, and are generally viewed in terms of recreational opportunities, physical beauty, prestige and the like. They reported on a survey conducted by the Coastal Zone Laboratory at the University of Michigan. This survey of shoreline

property owners indicated that aesthetic beauty was the most significant value. Therefore, any impairment of recreational opportunities, for example, caused by water quality problems will result in a decline of aesthetic values. In the limited case study they presented, the proportion of the property value attributed to aesthetics was more than 40 percent when the value of raw inland property was compared to that of similar, undeveloped shoreline property. We must be careful not to generalize this rather limited datum in a Canadian context, but given the lack of such information, it cannot just be discarded. Since it is based on limited scope and coverage, we can minimize any distorting impact on our thinking and avoid the logical fallacy of argument by extreme example through the analytical device of using it as a polar case. In other words, 40 percent is the assumed maximum property value loss due to impairment of the aesthetic appeal of shoreline property, however caused. The minimum loss is of course zero.

If these bounds on potential damages are accepted as plausible, the problem remains to decide on the proportions of this boundary assignable to water quality determined facets of aesthetic value. Little published evidence was uncovered to provide a factually based determination of these proportions. Further, individual preferences being as variable as they are make it difficult simply to impute such a ranking. Recall, however, that such extensive variability produces a wide boundary of sampling error around the central tendencies of the distributions of preferences. Given that we accept the hypothesis that water quality has an impact on shoreline property values that is not zero (our minimum loss assumption) then a choice of loss that lies somewhere in the lower half of the min-max range is likely to fall within the

normally expected confidence limits of statistical sampling. It also allows for the probability that some items of aesthetic value, such as prestige, are not so sensitive to water quality considerations. We are therefore left with potential damage range of 0 to 20 percent.

While our hypothetical derivation of potential damages might be based on some seemingly heroic assumptions, such assumptions are all explicit and involve no hidden analytical pitfalls or misplaced concreteness. While hastening to point out that comparisons with the results of Dornbrusch et al., (1975), and Ormerod, are inconsistent with criticisms raised earlier, it doesn't seem unreasonable to compare them given the explicit understanding here that both are subject to individual reader acceptability. The main point being that such criticism was designed primarily to evoke an awareness and skepticism that is largely absent in matters of analytical technique in social science. This comparison shows that the midpoint of the hypothetical range and the averages of the other studies are almost equal at about 10 percent.

Combining this 10 percent property value loss estimate with the data on Haldimand-Norfolk and Niagara counties yields a lower bound estimate of value losses associated with water quality problems of about \$9 million. For Lake Erie as a whole, the 1979 average value per metre, for all uses, is about \$680. This implies that the same two categories of residential land use have an approximate lower bound total value of almost \$180 million. Potential losses are therefore in the order of \$18 million. The whole lake estimates are probably serious underestimates as residential property generally has a higher value than other uses. The Niagara data in Table 2 contain a significantly higher proportion of

residential use and the value per metre at \$1,307 is partially indicative of this. It would probably not be stretching the truth too far if the loss estimates for Lake Erie as a whole were doubled to \$36 million.

The somewhat long and torturous route to the above loss estimates is only partially indicative of the problems associated with the question addressed. The extent to which these potential property value losses are representative of reality is unknown. As we have noted, there is no identifiable, smooth proportionality between water quality per se and residential property value. What quality is poor enough to produce the maximum loss and what improvement is necessary to reverse this loss are also imprecise matters. Throughout this discussion, it has been implicitly assumed that water quality problems would not be inordinately severe, or that health hazards might be present. In using the estimates developed here, one must keep these shortcomings in mind.

The Commercial Fishery

The Lake Erie commercial fishery is considered to have the largest fresh-water fleet in the world. Of total Canadian Great Lakes landings, 80 percent of the tonnage and two-thirds of the dollar value are attributable to this lake. Tables 3 and 4 provide data on landings and value in total and for selected species of importance. These data provide a clear indication of changes in the species composition of the catch. Those changes are generally at the centre of the debate over the general depreciation of the Lake Erie fishery caused by human induced stresses. A constantly recurring theme in this debate involves the well documented loss of so-called valuable, desirable, or high priced per-unit

species such as blue pickerel, herring, lake whitefish, lake trout and walleye. This loss has been accompanied by a correspondingly large increase in landings of yellow perch and smelt, which are considered to be less valuable and desirable due probably to the lower price per pound.

Historical descriptions of the Lake Erie fishery, and numerous articles on the complex of man induced stresses affecting it, constitute a voluminous literature which could not possibly be covered here. The Great Lakes Fishery Commission (GLFC), (1979), documented Table 5, containing no fewer than 18 human stresses on Great Lakes ecosystems. Each of these stresses has a literature of its own of varying quantity. While certain of these are deemed to be of greater significance to the fishery resource, it is simply impossible to separate out the individual influences and impacts.

TABLE 3

CANADIAN
LAKE ERIE COMMERCIAL FISHERY
LANDINGS AND VALUE FOR SELECTED YEARS
1900 - 1970

YEAR	TOTAL LANDINGS (lbs)	TOTAL LANDED VALUE (\$)	BLUE PICKEREL	HERRING	WHITEFISH	TROUT	YELLOW PICKEREL	YELLOW PERCH	SMELT	WHITE BASS
1900	10,495,573	311,060	-	6,525,733	401,425	2,066	1,218,171	694,739	-	-
1910	14,330,137	885,399	-	6,947,501	1,293,650	1,945	923,863	674,221	-	-
1920	16,812,023	952,474	3,354,523	9,561,284	838,304	1,044	166,013	1,232,881	-	-
1930	12,681,060	709,770	5,899,140	506,639	1,087,689	11,077	274,638	3,419,680	-	-
1940	9,767,998	690,052	2,012,345	585,062	3,136,556	21	426,291	1,993,542	-	-
1950	16,866,059	3,149,341	8,611,434	645,313	1,390,367	22	1,251,957	2,165,762	-	-
1955	30,285,209	3,841,516	12,037,390	96,034	399,021	27	4,773,000	4,752,791	2,039,913	4,505,135
1960	28,177,857	1,993,310	3,143	5,701	21,298	-	613,925	11,353,802	11,011,309	3,144,326
			(29¢)	(27¢)	(52¢)		(28¢)	(10¢)	(3¢)	(9¢)
1965	35,178,404	3,319,334	132	-	385	-	345,711	18,603,438	11,710,642	2,610,948
			(30¢)	-	(53¢)		(41¢)	(12.5¢)	(3¢)	(15¢)
1970	31,755,446	3,770,281	-	-	76	-	25,668	19,998,810	9,401,972	195,349
			-	-	(49¢)		(55.5¢)	(16¢)	(4¢)	(21.5¢)

Source: Ontario Ministry of Natural Resources, Fisheries Branch. (Joan Ridgley).

TABLE 4

CANADIAN
LAKE ERIE COMMERCIAL FISHERY
LANDINGS AND VALUE - 1971 - 1979

YEAR	TOTAL LANDINGS (lbs)	TOTAL VALUE (\$)	YELLOW PICKEREL	YELLOW PERCH	SMELT	WHITE BASS	TOTAL FOR SELECTED SPECIES
1971	29,075,559	\$ 4,254,692	30,175	13,917,611	13,130,175	92,027	27,169,988
1972	30,181,837	\$ 5,374,610	\$ 15,390	\$ 3,618,578	\$ 525,207	\$ 22,086	\$ 4,181,261
1973	39,829,146	\$ 7,038,437	\$ 50,751	15,593,455	10,518,667	1,755,858	27,918,731
1974	38,685,536	\$ 5,633,918	\$ 26,391	\$ 4,366,167	\$ 525,933	\$ 316,054	\$ 5,234,545
1975	30,548,620	\$ 6,009,093	\$ 65,472	18,035,184	17,062,201	1,496,885	36,659,742
1976	25,711,071	\$ 5,989,948	\$ 42,557	\$ 5,590,907	\$ 1,023,732	\$ 299,377	\$ 6,956,573
1977	35,853,556	\$ 7,736,701	\$ 234,154	12,204,921	15,800,169	2,346,146	30,351,236
1978	40,159,610	\$ 9,883,626	\$ 117,077	\$ 3,905,575	\$ 790,005	\$ 398,845	\$ 5,211,505
1979	40,839,668	\$ 17,555,598	\$ 124,943	8,212,667	16,931,453	2,563,103	27,822,166
			\$ 86,211	\$ 3,859,953	\$ 1,184,502	\$ 692,038	\$ 5,822,704
			\$ 253,955	4,645,805	17,189,618	1,120,408	23,209,786
			\$ 227,348	\$ 3,762,226	\$ 1,315,484	\$ 514,657	\$ 5,819,715
			\$ 529,453	8,509,755	22,993,548	986,283	33,253,193
			\$ 466,948	\$ 4,953,965	\$ 1,605,140	\$ 541,147	\$ 7,567,200
			\$ 588,838	8,805,838	26,608,833	1,648,767	37,652,276
			\$ 557,906	\$ 5,928,350	\$ 2,176,782	\$ 1,054,439	\$ 9,717,477
			\$ 1,195,179	12,050,722	23,856,967	1,679,487	38,782,355
			\$ 1,515,224	\$ 13,139,998	\$ 1,978,773	\$ 752,618	\$ 17,386,613

Source: Ontario Ministry of Natural Resources, Fisheries Branch. (Joan Ridgley)

TABLE 5

LIST OF HUMAN STRESSES ON
GREAT LAKES ECOSYSTEMS

1. Fishing and other harvesting of biota.
2. Introductions and invasions of exotic species.
3. Microcontaminants, toxic wastes and biocides, from industry and agriculture.
4. Nutrients and eutrophication from sewage plants, agricultural and urban run-off.
5. Organic inputs and oxygen demand from sewers, canneries, etc.
6. Sediment loading and turbidity, from agriculture, construction sites, and resuspension.
7. Stream modification-dams, channelization and logging, changes in land use.
8. Dredging and mineral, sand, gravel, and oil extraction.
9. Filling, shoreline structure, offshore structure.
10. Water level control for shipping, electric power production, wetland management, etc.
11. Dyking and draining of wetlands.
12. Weather modification, mostly industrial.
13. Water diversions between the Great Lakes basin and other basins.
14. Entrainment and impingement in water intake structures.
15. Thermal loading from cooling water, mostly in electric power plants.
16. Ice control for navigation.
17. Major degradative incidents or catastrophies.
18. Acids and toxic chemicals transported by the atmosphere.

The general qualitative impacts of each stress are well documented in, for example, Regier (1973), Christie (1974), Beeton and Edmondson (1972), Smith (1972), Hartman (1972), Colby et al. (1972), Leach and Nepszy (1976), Nepszy (1977), Leach et al. (1977), Regier and Hartman (1973), and GLFC (1979). Social, economic and institutional aspects of the fishery are covered in Kendall, Paine and Sinclair (1977), Lambert (1975), and Sinclair (1978) among numerous others.

The sections on resource uses covered above concerned impacts on man's technology and artifacts. In contrast, the impact of eutrophication on the fishery involves an incredibly complex and relatively poorly understood living system. A meaningful understanding of such a complex can only be achieved through a holistic, ecosystem perspective. As Johnson (1980) notes, the management of water quality alone is an inadequate tool to protect or understand aquatic resources. The obvious truth is that man induced stresses have produced gross changes in the entire Lake Erie ecosystem. While phosphorus control is being undertaken, a whole host of other stresses continue on unabated and/or accelerating. This whole complex of stresses needs to be addressed simultaneously, because lacking such attention, phosphorus management strategies might lose a great deal of their relevance.

A brief overview of the impact of eutrophication on the fishery appears warranted. The general literature consensus appears to support the argument that of the major stresses on the fish component of the Lake Erie ecosystem, the dominant impact until about 1945 was the unregulated

and opportunistic fishery (Regier 1972, Regier and Hartman 1973, Kendall, Paine, and Sinclair 1977). Data in Regier (1973), indicate that fishing pressure steadily increased yields of the preferred species up until about 1900, following which the oscillatory character of yields appeared to indicate a resource under stress. This extreme variability in landings continued until 1945-1955, when collapse occurred. Two additional primary stressors are implicated in this collapse and the subsequent ecological transformation that emerged. Eutrophication should (under conventional thinking) originally have resulted in an expected increase in the ecological production of fish. However, some authors suggest that resultant impacts on hypolimnetic oxygen depletion rates in the central basin, and on spawning, resting and feeding habitats tended to make the preferred species more vulnerable to the predation of the fishery and other stresses, thus reinforcing the fluctuations and eventual collapse (Regier and Hartman, 1973). This point concerning the impact of hypolimnetic oxygen depletion is actively debated by several researchers. Lee and Jones (1979 b) and Charlton (1980) argue that hypolimnetic oxygen depletion is a long standing problem that probably hasn't changed much for 20 or 30 years. It is suggested that the rapid eutrophication that took place during the last 20 years or so had limited impact on the cold water fishery. This question is not resolved, however, as Burns and Rosa (forthcoming) are preparing new data calculations that appear to identify significant and identifiable changes in various phosphorus and oxygen related variables that support the viability of objectives associated with hypolimnion oxygen depletion. Also of importance, Regier and Hartman, among others, suggest that the invasion of Lake Erie by the rainbow - smelt in 1931 probably eventuated the final collapse of the premium species. It is also worth noting that

catch statistics do not necessarily indicate abundance. Failure to recognize this fundamental fact probably further aggravated the voracity of the unregulated fishery.

These three major stresses, together with the rest of the long list, acting separately and jointly, transformed the Lake Erie fish community from one dominated by large benthic forms to small pelagic ones. These new species are low-priced per pound (although perch now pays about \$1.00 per pound landed weight) relative to the now commercially extinct premium species, although the biomass of annual catches has remained high. Also, the resultant increases in yellow perch and smelt yields without question reflect real abundance increases. It is worth noting, however, that from the early 1950's to the present, annual catches have ranged in the 30 to 40 million pound area. Christie, (1974) and Regier (1973), among others, note that contrary to conventional wisdom (Oglesby 1977; Lee and Jones 1979) the greatly increased nutrient loadings and phytoplanktonic production in recent decades have not led to greatly increased fish yields over the original system, mainly because the smaller, more efficient species arrays that now dominate the community are not able to exploit fully the resources of the lake. Christie adds the caveat that this may be due in part to heavy fishing and pollution.

The general consensus that seems to emerge from the literature is that the overall environmental changes in Lake Erie are such that salmonids and coregonids, such as lake trout, whitefish and lake herring, are not likely to survive on a self perpetuating basis, however, the lake is well suited for percids, like walleye and yellow perch.

To return to our earlier discussion, we know that water quality, as measured by trophic status, is only one variable in the determination of the Lake Erie life support capability for fish communities. In actual fact, the entire lake ecosystem has been grossly and irrevocably modified by numerous stresses, all of which affect the lake's capability to support healthy aquatic life. Some of the impacts are understood, but there are many aspects that are not fully appreciated nor even recognized. In the face of such a multi-faceted system it is important to understand one fundamental aspect of the set of conditions affecting the aquatic ecosystem. That is, as Johnson (1980) and others imply, while water quality improvements and phosphorus management are necessary for the protection of aquatic ecosystems they are not sufficient. Similarly, the relaxation of other stresses is also necessary but not sufficient.

In other words, while the relaxation of each individual stress may be necessary but not sufficient for a permanent improvement in aquatic ecosystem health, many of them individually are sufficient for the destruction of the ecosystem if not relaxed.

This notion is related to those we discussed in the introduction. The lake ecosystem reached its present condition through integrated physical, chemical and biological process responses to the perturbations listed in Table 5. Aquatic ecosystem health is an emergent property of the dynamic Whole; such property being a multi-faceted, qualitative, dynamic state that is not reducible to a

signal registration alone. Rehabilitation of the aquatic ecosystem therefore depends on a reduction of all external stresses and the resultant integrated ecosystem response to such changes. Therefore, while phosphorus management is necessary in any case and can be considered as a separate issue, we must recognize the lack of sufficiency of such considerations alone. By the same token, however, we must also remember that a true ecosystem perspective cannot be reduced to either the whole alone or to the parts by themselves.

Returning to phosphorus management in particular we confront another characteristic of natural phenomena. This aspect concerns the importance of historical time. Like time's arrow, natural system changes induced by man are unidirectional in the sense that we cannot run history in exact reverse. We can only move forward in time and observe what unfolds. In some cases, changes can be reversed, but since each case involves novel phenomena we cannot generalize such observed reversals to other situations. Such regularity or permanence is generally absent from the organic and superorganic domain.

As Regier (1973) notes, what will happen to fish communities in aquatic ecosystems when nutrient loadings (or other stresses) are relaxed depends very much on the condition of the ecosystem at the time of such changes. Specifically, management strategies can only affect the fish community as it now exists. The future will be much more a reflection of the present situation than anything that has previously existed. In the case of Lake Erie, to the extent that the present dominant species arrays represent an evolutionary type stress-response, we can never, repeat never, reverse this. In this sense, and it appears realistic, the

commercial fishery as it once was is gone forever, like the past from which it came. While it may be worthwhile to have the rehabilitation of premium species as an objective (for example, selected salmonids for the sport fishery), the likelihood that they can once again achieve their past status appears to be less fact than it is fancy.

It seems then that one focus of phosphorus management strategies should relate to protecting the integrity of the existing ecosystem and related fish communities. This has a number of implications for specific program objectives. The main impact of eutrophication on the percids, which (aside from smelt) form the backbone of the present commercial fishery, appears related to reproductive behaviour. The inshore areas are important habitats for percid species, and spawning aggregations tend to occur in these areas or in rivers. (Leach et al., 1977). Unfortunately, human influence is greatest in the littoral environment, and as nutrients are added there, it is usually first affected by excessive phytoplankton production. As Johnson (1980) notes in reference to the designation of 'limited-use zones', the degradation (including but not limited to nutrients) of the nearshore habitat may be the Achilles' heel of aquatic communities. While we are not certain how excessive phytoplankton production will really affect percid spawning, these points suggest that a comprehensive phosphorus management strategy should contain a distinct spatial component oriented towards the near-shore in general, and with regard to critical or important percid habitat areas in particular, if such are identifiable.

This observation might be interpreted as being at odds with the 1978 Agreement goal of achieving year-round aerobic conditions in the central basin hypolimnion. Such a literal comparison would ignore the essential fact that it is the whole lake that is the 'boundary' water, not the nearshore zones of the individual countries. Since the major terminal effect of eutrophication is oxygen depletion, it provides a convenient, measurable (with difficulty) benchmark that relates to the whole lake perspective necessary for the formulation of an international agreement. In the actual implementation of policies to fulfill Agreement obligations, each country is free to choose those actions that provide ecosystem enhancements deemed most beneficial, and still stay on the path to the ultimate oxygen objective.

The overall effectiveness of alleviating the eutrophication problem will ultimately depend on how well we understand and deal with the other stresses on the aquatic environment. While each has its own particular properties and problem framework, they exist in isolation only in man's mind and his analytical representation of them. In nature, all are acting together as well, and true understanding and effective management plans will only emerge from an ecosystem perspective. This is clearly beyond the limits of the present exercise. It is useful, however, to note briefly the present status of several of the major stresses that appear critical to the fish community.

Some authors argue that the single most significant stress is still the commercial fishery (Kendall, Paine, and Sinclair, 1977). The Commercial Fishing Harbours Study, Fisheries and Oceans Canada, (1980) reported data on anticipated commercial fishing harvests through 1985

that were substantially above (21 percent) the theoretically sustainable harvest, and even more above (38 percent) the recommended annual harvest that allows for stock rehabilitation and maintenance. (For the record; potential was set at 30,700,000 lbs; anticipated at 37,100,000 lbs; and recommended at 26,900,000 lbs). While such estimates are invariably "soft", and others exist that are lower, it is nonetheless significant that pressures remain to harvest beyond sustainable levels as estimated. Perhaps some lessons are still to be learned from the mercury ban on walleye fishing in the western basin. After several years the stocks recovered markedly, raising some obvious points concerning harvest pressure.

It would be difficult to provide any appreciation of the toxic contaminants issue and potential impact on the fishery in a short space here. What happened to the walleye is a reflection of a distinct possibility for the entire fishery. In addition, all other remedial programs would be down the drain if the fish are unfit for human consumption. Johnson (1980) gives a brief overview of past incidences.

One final stress of note concerns impingement and entrainment of fish due to cooling water withdrawals by power plants. Kelso and Milburn (1979) estimate that impingement on intake screens causes direct losses to fisheries equal to 25 percent of the annual commercial harvest. Entrainment is also serious as such large numbers of young-of-the-year fish (over 10^9 annually) are involved that it is suspected that recruitment is affected. While almost all of this problem, as it affects Lake Erie, involves power plants on the U.S. side, such a large impact

cannot be ignored over the long term. It also serves to illustrate further how significant non-water quality issues are to the aquatic ecosystem.

In conclusion, it is necessary to provide some estimate of the potential social and economic impact of phosphorus management on the commercial fishery. Trying to relate incremental changes in water quality to fish yields and economic value is a waste of time for Lake Erie since no realistic relationship can be estimated. In fact, in such a complex and stressed system, it is entirely possible that over relatively wide ranges of water quality, no real discernible change occurs. Instead, it seems reasonable to expect that a management policy that allowed a substantial deterioration in the nearshore percid habitat, would likely result in increased instability in natural reproduction. Since it is difficult if not impossible to predict the collapse of individual stocks and the resultant impact on the overall fishery, it might be more useful to describe what a management policy protects. The Commercial Fishing Harbours Study (1980) estimated that the net value of the harvest (after costs of production) is about 70 percent of the gross. In 1979 the landed value was almost \$18 million, so a rough estimate of the net direct loss would be about \$13 million per year. In addition, there were almost 700 fishermen (although this estimate varies) employed in the primary sector, in 1978, operating boats and equipment worth \$14 million. In the event of a collapse of percid stocks the industry would likely become a losing proposition. If the industry collapsed this entire investment would essentially be lost as there is little value in alternative employment. From a social perspective, fishing for a living is one of those occupations that is inexplicable to

much of the urban middle-class population. In turn, the hustle and bustle of Bay Street in Toronto would be intolerable to the average fisherman. This is a prime example of the irreducibility of the quality of life to simple dollars. This dedication to a way of life also increases the participants vulnerability, as little in the way of alternative employment opportunities exist in the predominantly small, rural communities that form the home base of the industry. The loss of the fishery would result in substantial disruption as employment seekers would generally have to move or assume long commuting obligations. A more detailed socio-economic description of the fisherman population is included in Sinclair (1978).

Recent work done at Brock University (Berkes pers. commun.) shows that one large processor, eight intermediate, five small, and ten fishermen processors operate plants on Lake Erie, generally located on the harbours accomodating the large number of vessels and landing the most fish. It is estimated that these plants employ 190-205 workers and supervisors for varying lengths of the year. It is not possible to say what would generally happen to these facilities and their employees in the event of a fishery collapse. Undoubtedly, some would fold, however, the largest processor, Omstead Foods, now uses most of its capacity for frozen vegetables (Berkes, pers. commun.)

Water Based Outdoor Recreation

As pointed out in the introduction, it is generally believed that an increase in water-based recreation activity will be the major source of benefits to be derived from water pollution control.

Unfortunately, as Freeman (1979 p. 195), points out; "There is a substantial body of literature on the theoretical and empirical aspects of estimating the demand for recreation but relatively little work has been done on the role of the attributes of recreation or the benefits of improved recreation opportunities. Integrating water quality into the analysis of recreation demand is the major research task that must be confronted before sound estimates of the recreation benefits due to water pollution control can be provided".

These difficulties with dollar evaluation arise because the recreation resources in question are generally non-priced. Market evidence of the demand for recreation, in the form of quantities of recreation consumed over a wide range of user fees, is generally absent. To overcome this lack of market directed price signals a number of approaches designed to provide indirect, proxy values for recreation have been conceptualized and widely discussed in the literature (See, for example; Freeman, 1979; Dwyer, Kelly and Bowes, 1977; Sinclair, 1974). Those methods considered to have the most merit attempt to estimate some form of willingness to pay on the part of recreationists. Aside from requiring complex and costly surveys, these methods need to satisfy such stringent assumptions that their general validity and usefulness is difficult to predict. In any case, in their present state of development none of these methods can even begin to deal with how recreationists might value alternative quality states of the aquatic environment.

Other attempts at quantifying the dollar value of water-based recreation (or any recreation activity) resort to using the amounts people spend on the goods and services associated with such activity.

Examples of the use of such expenditure data are widespread, testifying to the appeal of this method. For example, we are often reminded that in the Province of Ontario tourism and recreation account for about \$10 billion dollars or 11 percent of Gross Provincial Product. This makes this sector the third largest in absolute terms, and as well, it has the largest growth rate of any activity in the Province (and in North America). These data indicate that we are dealing with a large and important activity that is obviously highly dependent on the natural environments within which such activities take place. More specifically related to our focus, the Fisheries and Oceans Canada report, Program for Recreational Harbours in Ontario, (1979), made a great deal of use of such data. They reported that expenditures in Ontario, in 1979 dollars, on boating and fishing "operating" equipment totalled about \$212 million. This was in addition to a direct "capital" expenditure of almost \$480 million on boats, motors, and equipment. Of this "capital" expenditure, about \$27 million was spent in the Lake Erie consumption zone. Tuomi (1979), reported that the Ontario sport fishery had expenditures and wholly attributable investment of anglers totalling about \$563 million in 1975. He also presents data on employment and other economic indicators in support of his argument that the sports fishery represents a substantial, but relatively unappreciated natural resource. Unfortunately, the data he uses to support the sport fishery are substantially the same as those used in the Harbours Study. Such multiple attribution of the same expenditures is a commonplace practice. While probably not done willfully, it is misleading to say the least.

This kind of data is informative, and within limits, useful. It is, however, subject to a great deal of misinterpretation, and is fundamentally irrelevant as a measure of the primary benefit recreationists derive from direct participation in a particular activity. Cauvin, (1978), agrees, in noting that; "such expenditures are for boats, motors, food, lodging, travel, clothes, rods, and similar items. These values account for the dollars spent, and there is nothing left over as a return to the recreational use of the land". In any case, why should these expenditures necessarily be considered benefits, when in most cases they are costs incurred to participate in a desired activity. While such proxy representations of value are most often justified by the absence of directly observable indicators, the inherent logical ambiguities involved make this approach of little value as a guide to public expenditure decisions (Dwyer, Kelly and Bowes, 1977).

The true value of the recreation experience derives from the associated psychic flux, and might reasonably bear no relationship (or even a negative one) to the amounts expended in the pursuit of that activity. Attempts to estimate a valuation of this flux might be more fruitful if they concentrated on the direct man-environment interactions that really underly the rationale for recreation participation. For two million years our ancestors were hunters and gatherers; our intrinsic affinity with nature is derived from our genes; it is spiritual, not material.

For present purposes we will adopt this view, and proceed on the basis that it is the actual recreation and/or participation itself that provides the spiritual or psychic flux of interest to our problem.

Drawing on the general literature consensus and Freeman (1979), it appears that the most fruitful approach to monetary evaluation is likely through the use of recreation participation surveys and the development of plausible unit values. Sinclair, (1978), presents data describing the estimated numbers of individuals that visited Lake Erie for recreation purposes during 1977. While he provides detailed breakdowns on socio-economic characteristics and reasons for visiting, among other data, for our purposes the number of visitor days and the principle activities undertaken will suffice. Table 6 contains data on activity days for visitors directly using Lake Erie for recreational purposes. The term "direct use" is used to distinguish those visits that involve contact with the lake's water and/or consider the lake itself as a major reason for visiting the area. Additional data provided indicated the proportions of discretionary time devoted to specific activities. Those involving some form of water contact proved to be the most significant with swimming accounting for almost 18 percent of activity, followed by recreational boating at 15.3 percent and pier fishing at 12.3 percent, for a total of 45.6 percent. Other important activities included walking for pleasure, 9.9 percent; outdoor games, 12.6 percent; and social campfire gatherings, 10.7 percent.

A major analytical hurdle involves deciding how significant eutrophication related water quality is to the enjoyment or enhancement of the overall recreation experience and its inherent division of activities. Sudar (1978), noted that boating is basically a 'non-contact' water-based activity and compared to fishing and swimming, is less demanding of water quality. Fishing is an 'indirect contact' sport, requiring water quality that varies depending on the species

fished. Swimming is most demanding of water quality as it is a 'direct contact' activity. In addition, water quality has a dual impact on recreation. It affects the total number (quantity) of participants and also, perhaps most significantly, the quality of the experience for all participants. We must acknowledge that people travel to the lake for many reasons, with water quality being one. It is also apparent that even during the late 1960's and early 1970's, when eutrophication was at its worst, people still used the lake as a recreational centre. The standard economics literature responds to this knowledge gap by claiming that we don't have enough data, but if we did it might be possible to discover the relationship between participation rates and the quantity and quality of recreation opportunities (Freeman, 1979). It is difficult not to take exception to this simplistic statement. First, there is a myriad of factors that enter into an individual's decision process involving recreation activity and site selection. Such things as accessibility, convenience and transportation options are often as important as site specific attributes. To simply claim that data limitations preclude the possible discovery of the law governing participation is gross oversimplification of the worst kind. Secondly, more data or facts do not necessarily lead to greater knowledge, but might in fact render the task of understanding increasingly more difficult. In reality, the choice situation facing the recreationist is, as we have amply seen throughout this paper, fundamentally qualitative and constantly changing. As in evolution, such a situation involves nothing that is general or definitive. The upshot of all this is that we are once again in an analytical box. On the one hand, we know that water quality is an important determinant of the quality of the recreation

TABLE 6

TOTAL NUMBER AND PERCENTAGE OF ACTIVITY DAYS DIRECTLY
USING LAKE ERIE FOR RECREATIONAL PURPOSES ACCORDING TO
RESIDENT CATEGORY DURING 1977

	<u>Boaters 1</u>		<u>General Recreationists</u>	
	#	%	#	%
Resident	2,953,000	75.0	37,191,000	82.4
Non-Resident Can.	740,000	18.8	7,529,500	16.7
Non-Resident	<u>242,000</u>	<u>6.2</u>	<u>411,500</u>	<u>0.9</u>
TOTAL	3,935,000	100.0	45,132,000	100.0

1 Boater Activity days involve all the recreational activities participated in by these identified as "Boaters", including recreational boating.

SOURCE: Sinclair (1978).

experience. On the other, we have no way of separating out the influence of this single factor from the myriad others. Recognizing the constraining nature of these boundaries on our understanding, our ability to assess the value of water quality changes in the context of recreation activity is restricted to subjective evaluations based on information available at the boundary. In part, this information consists of varying levels of detail concerning the activity days listed in Table 6. At one level, we can consider gross activity days and attempt to impute plausible subjective evaluations of an enhanced experience due to improved water quality for the total number. At another level, we can view sport fishing and swimming as being the activities that are primarily related to water quality and evaluate only them. A third alternative is a combination of the first two; swimming and fishing are separated from the rest, but all are evaluated.

Before we proceed any further it is absolutely essential to understand that we are not dealing primarily with a quantity response by recreationists to water quality improvements. As noted earlier, leisure activity is the growth industry in the Province. Normal population growth, and changing participation rates will result in increased recreational use of Lake Erie for reasons that have nothing to do with water quality. Separating out the part of this natural growth component that is associated with eutrophication is not possible with the present state of knowledge, and perhaps might never be. So in terms of the quantity response, we will have to content ourselves with plausible hypotheses. A further caveat concerns the overlapping nature of the activities that go into the overall recreation experience. For example,

are the boaters sport fishermen, pleasure boaters, swimmers, campers, etc., or all of these? Such questions reveal the real complexity of the problem once one inquires beyond the subtle seductiveness of the seemingly objective numbers that claim to portray individuals as belonging solely to a particular activity class.

At the broadest perspective we can hypothesize plausible dollar values that recreationists might attach to an enhanced experience due to eutrophication related water quality improvements. We will assume that recreationists perceive such quality in terms of clarity, algae or lack of it, and other visible symptoms of eutrophication. We further assume that clearer, cleaner, water is unambiguously preferable, however, such perceptions are purely subjective and different quality states might be ranked differently between individuals.

To develop our evaluation criteria we can draw an analogy to the standard Paretian model of welfare economics (Winch, 1971; Junger, 1979). In this model, an individual considers a good, service, experience, or even his own labour and assigns a subjective value to it. He compares this subjective value to the market price of that item and, if the price is less than that value, he will consider buying it. In the case of his own labour, if the price is greater than that value, he will consider selling it. In the economics jargon, the subjective value is marginal utility (disutility in the case of labour), and corresponds in reality to the incremental addition (subtraction) to the enjoyment of life that the item in question offers. Note that all transactions are of course constrained by the individual's income level. Note also, that this market price determines only the minimum value that the item has to

the individual. An obvious example of this principle relates to the price we pay for potable water. Clearly then, if the subjective value of any item increases, the logic of the Paretian model indicates that one would be willing to pay more for it (ignoring labour). This would appear to establish a conceptual basis of individual willingness to pay for increases in the enjoyment of life related to quality improvements in the objects of economic choice. It is also common sense.

Having established a logical basis for individual willingness to pay for environmental quality improvements, the problem remains to determine the amount. Since most such resources are unpriced, or nominally priced, there is no benchmark from which to gain some initial perspective. Previous studies have concentrated on estimating the total willingness to pay for a given quantity and quality of experience.

For the sports fishery there are a number of examples of such estimates. The GLFC (1979) report noted a 1979 Michigan study whose preliminary results indicate a net benefit value of about \$21 per angler day. Another cited study indicated that Wisconsin Lake Michigan anglers showed that they would be willing to pay an average \$3.25 if they could catch one additional fish per day. The Montreal Engineering Study (1974) considered possible pollution related damages to sport fisheries across Canada. While insufficient data was available to evaluate Ontario specifically, the per day valuation of angling ranged from \$10 for trout to \$20 for salmon, in 1972 dollars.

In considering general recreational use of beaches, the IJC Reference Group on Regulation of Lake Erie (forthcoming), estimated a value of an activity day on the Canadian side of Lake Erie at about \$8. Estimates for the U.S. side of the lake were based on a version of the travel cost method and ranged from about \$3 to almost \$15 per user day, with the average being about \$7.

It is important to recall that these estimates represent the minimum value that the activity has to the individual. Being based on willingness to pay, such valuations are constrained by personal income levels and the implicit perception that the individual can still participate as much as he wishes. In other words, he doesn't have to give anything up. An alternative perspective would involve the willingness to sell evaluation, where income is not a constraining factor and where the sale of opportunities may exclude the individual from participating. The significance of this comparison becomes apparent once one realizes that the willingness to pay argument involves the implicit assignment of property rights or resource rights of the environment to the polluter. The alternative, willingness to sell arguments, on the other hand, assign the property rights to the non-polluting activity or user. Since buying is constrained by the user's income and selling is not, it is easy to see how the same choice might involve very different monetary valuations. The importance we attach to this distinction has profound implications because concentrating on willingness to pay involves the implicit value judgement that we consider pollution to be the more important activity since we assign the original resource rights to it. This is a point of fundamental importance and bears close thought and deep consideration (Fisher and Peterson, 1976). Of particular note

is that this hidden value judgement is one of the most significant sources of environmental problems in general. This arises because it is not generally acknowledged that the money price evaluation that is determined by the standard economic framework is based entirely on the initial distribution of the ownership of the property resources in the system. Moreover, if this initial distribution is changed, the money price evaluation will also change. These facts lead to the brutal truth that to try to judge proposals for environmental management policy on the basis of a money price evaluation derived from a distribution where rights to the environment are assigned to the polluter simply reinforces the pollution problem. In other words, standard evaluation techniques are inherently biased towards the status quo. (Alston, 1980).

It is essential to understand that conventional methods of evaluating costs and benefits are not the technical, value-free analyses that they purport to be, but rather are ideological, subjective and inherently arbitrary. With this in mind we should feel free to allow our own reasoning processes the freedom to decide on the plausibility of alternative valuations. Taking all of this discussion into consideration we must proceed with the selection of plausible values of two items:

- (a) monetary measures of enhanced enjoyment per activity day due to eutrophication related improvements in water quality; and
- (b) a differentiation of activities due to distinctive variances in water quality-activity relationships and therefore subsequent differences in impacts due to phosphorus management.

With respect to (a), we can integrate the following information. Ignoring the difference in the timeliness of the data, and subject to the above criticisms, it appears that what work has been done imputes a minimum value of from \$3 to \$15, averaging \$7.50, for a generalized recreation day. For sports fishing comparable values range from \$10 to \$21, or a \$15 average. In addition, the Wisconsin and Michigan studies suggest that anglers would be willing to pay \$3.25 extra per day, over and above an approximate \$21 total valuation, or about 15 percent. Considering generalized use of beaches, Savill (1979) attempted to measure the intensity of public preferences for beach water quality using the Von-Neuman-Morganstern gamble technique and reported that the interviewed public preferred 'clean' water to 'dirty' water with an intensity factor of more than 3 to 1. In other words, when presented with pictures portraying actual differences in visual water quality, the methodology indicated that crudely quantified utility for the clean water was more than 3 times that expressed for the dirty water. I would prefer not to be overly confident in such results since the methodology contains numerous pitfalls; however, they are useful in giving us some notion of preference intensity.

This limited information does not provide us with a sufficient basis on which to make direct inferences concerning the potential value of water quality improvements. Since no such independent information exists we will have to combine our imagination with a little common sense and simply posit a plausible value for illustrative purposes. We should not be at all averse to doing so since we have the key to the mental shackles that demand value-free methodology and numbers: no such

methodology and numbers currently exist in social science. (Gordon, 1977). We can temper this free choice by adding a little method of our own. By choosing a nominal sum that is deliberately low, the plausibility of the discussion is heightened. In view of these considerations it would appear that for situations that exclude gross water quality deterioration, a minimum value of \$1 per activity day of generalized recreation for improved water quality would be suitably low and also consistent with the values presented above. For sports fishing, improvements in water quality that had identifiable impacts could range in value from \$1.50 to \$3 per angler day, and be consistent with previous estimates. It must be emphasized that the referenced estimates are limited in their representation of quality of life value. At the most obvious level, their small magnitude seems almost laughable when compared to the hundreds or thousands of dollars that are spent on ancillary items. On a more fundamental level, there is a good deal of argument supporting the view that damage functions exhibit increasing marginal damages from pollution (are convex) because of diminishing returns to the assimilative capacity of the environment and to biological defense mechanisms (Fisher and Peterson, 1976). In the present context, this implies that individual willingness to pay is not a constant, but dependent on the initial quality state from which improvements are to be made. In this sense, relatively poor water quality might yield a low, total willingness to pay, but a higher, marginal willingness to pay for improvements. There are numerous other comments that could be made in this vein; the point being that the limited scope of the methods used to derive money prices in the absence of actual voluntary exchange generally yield valuations that are ludicrously low compared to the real underlying values. It is therefore reasonable to ask why one would derive such

prices at all. In the present case I suggest that they be used for illustrative purposes only. Their usefulness depends on how comfortable we are with them and any policy directions they suggest. As will be noted later, it may be more useful to recognize that the price of something is only the amount of other things (not necessarily calculated in terms of money) that would be exchanged for it.

Utilizing the activity day estimates in Table 6, we can state that if participants perceive that water quality improvements increase their subjective valuation of a generalized recreation day by the equivalent of \$1, this would amount to a total of almost \$49 million per year. Differentiating recreation by specific activity is extremely difficult, in part because of reasons discussed above. The sport fishery presents particular problems for several reasons. As we noted in the section on commercial fishing, many stresses are acting on the fish community. Also, some counter-arguments concerning the impact of phosphorus management exist. Berkes (pers. comm.) noted the work of others indicating that further reduction in phosphorus may result in less fish production and hurt the sport fishery by restricting the introduced salmonids to the shoreline areas that are rich enough to support them with forage species. Also, the perception of an enhanced fishing experience depends critically on individual preference and enthusiasm for the sport. While a detailed discussion of this activity was considered for inclusion here, further reflection on the complexity of the issue made that appear inadvisable as nothing definitive could be said that wasn't obvious or better stated elsewhere. Instead, some estimates of money value will be offered and the reader can decide on their merits. Using Table 6, and the estimate of activity time devoted to pier fishing

yields an estimate of just over 6 million activity days. It was further estimated above that an enhanced fishing experience was worth between \$1.50 and \$3, or \$0.50 to \$2 more than a generalized day. This implies that water quality improvements that enhance this experience provide an additional \$3 million to \$12 million in value per year. Other information on sport fishing in Paine, Kendall and Sinclair (1977) and Cox and Straight (undated) indicated that there were 160,000 resident licenced anglers in the Lake Erie tier of counties in 1970. They fished on estimated total of over 3.3 million days. Assuming that the Canada-wide growth trends contained in Tuomi (1979) are representative of Lake Erie, angler days based on this data would have approximated 5.2 million by 1977. This estimate is reassuringly close to Sinclair (1978), particularly since it is based on a fundamentally different population and sample. This narrower coverage is consistent with the lower estimate. Further differentiation by activity, while desirable, would serve little informative purpose since we have no further quantified valuation distinctions beyond the two used.

In summary, our illustrative estimates indicate that improvements in eutrophication related water quality that provide an enhancement of the recreation experience have a minimum valuation of between \$52 million and \$61 million per annum (for 1977 levels of participation). Importantly, this pertains to the number of recreation activity days that existed before the improvements in water quality. As we noted earlier, there would also be a quantity response, as individuals who did not participate before for reasons of water quality, would do so after the improvements. At the present time, we have no analytical basis or data on which to base an estimate of this demand response. Anecdotal

evidence from newspapers, other printed media, and personal conversations and experience indicate that quality improvements are perceived to have occurred in Lake Erie as regards recreation experience and that a directly related participation response has occurred. Again, we will simply intuit an estimate of this demand response, and let the reader decide. If we assume that the cumulative increase in activity days (given a number of years to equilibrate), due to water quality improvements only, will total 5 percent, this implies an additional 2.45 million activity days at 1977 levels of participation. At a minimum, generalized use level each of these days can be imputed a money value equal to the average total willingness to pay; \$7.50, plus the value of the quality improvement; \$1, or \$8.50 per day. This makes the value of the quantity response a minimum of almost \$21 million. Additional value due to a higher valued angling will not be considered here. Given that this estimate is pure hypothesis, the reader can disagree and/or substitute their own guess, however, 5 percent is not an unduly large response.

In conclusion, our illustrative example provides some indication of a money valuation of an enhanced recreation experience due to a perceptible water quality improvement. While both 'valuation' and 'perceptible' are malleable terms, they are admittedly so, unlike most conventional analyses that hide these inherently qualitative attributes behind a facade of so-called "scientific objectivity". Also, we largely abstracted from specific water-related activities of which there is a long list. Of this I don't see any general solution. As I have attempted to indicate throughout this paper, the inherent qualitative and changing nature of life processes, and in particular, of our thought

processes, prevents us from reducing everything to a deterministic, quantitative model. Furthermore, as far as we know, with few exceptions there is nothing we can do about this situation.

III COSTS OF REMEDIAL MEASURES - PAST AND PRESENT

The formulation of comprehensive phosphorus management strategies requires an adequate understanding of the financial costs associated with past and projected future remedial measures. The annual progress reports of the Great Lakes Water Quality Board contain estimates of funds committed for municipal sewerage construction in the Great Lakes basin. These are contained in Table 10. Detailed consideration of these reported figures yielded the significant observation that the estimates lacked a clear, unequivocal relationship to either past or future requirements for meeting Canada-U.S. Agreement objectives for phosphorus loadings. Some arguments claim that it was the advent of concern for phosphorus removal that resulted in the decision to build treatment facilities in an accelerated way. Thus it is claimed, the whole raison d'etre of the program was phosphorus removal. These claims are fine as far as they go, but I would argue that they are only partially justified. Like all partial truths, however, such a position can have some unfortunate effects upon our thoughts which we would do best to avoid.

Given the dense, urban culture that inhabits the Great Lakes basin, the vast majority of these costs is overwhelmingly related to the need to treat wastewater for human health reasons alone. These monies are expended for major trunk lines, pumping stations, treatment plants,

and effluent outfalls. According to Ontario Ministry of the Environment (MOE) sources, about 40 percent of annual expenditures are allotted for the removal of raw wastewater from a growing population base. Approximately 60 percent is spent on sewage treatment facilities with a primarily pollution abatement function. This primary function has a limited relationship with the removal of phosphorus. Rather, it is performing the absolutely necessary task of assuring that the serviced population does not drown in its own excrement. The position that such facilities are, nonetheless, all required for phosphorus removal, and that human health protection would require only chlorination, is incompletely founded. The acid test of such a position would be whether or not such expenditures would cease entirely if phosphorus removal programs were abandoned. I submit that they would not for obvious reasons. While the phosphorus loadings objectives as presently stated required some incremental costs at the treatment plant, such costs are relatively small and largely separable from overall wastewater collection, transport, treatment and disposal costs. Therefore, the position taken here is that to consider the financial commitments in the annual water quality reports as relating only to the phosphorus management issues of the Canada - U.S. Agreement is gross error and fundamentally misleading. Of further import, the water quality - water use relationships discussed earlier in this paper were concerned with the impacts of phosphorus related water quality only. These impacts are almost incidental when compared to the fundamentally larger implications involved in the release of totally untreated raw sewage into the Great Lakes ecosystem, particularly at current population levels and density. With this point firmly established then, the relevant costs for our

purposes are those solely related to the incremental provision of phosphorus removal capabilities; or the incremental policy costs as denoted by the PMSTF.

According to MOE sources and a report entitled, Summary Report on the Phosphorus Removal Program (1976), the installation of phosphorus removal equipment cost about \$15 million in capital costs for the entire Great Lakes Basin. An additional \$6 million was provided for related research studies, however, it is unclear that more than about \$2 million was ever spent. Being generous, a liberal estimate of first time costs for phosphorus removal in the entire basin would be \$20 million. For Lake Erie, the 1 mg/L objective was essentially achieved by the end of 1973, as planned. Roughly calculated, the Lake Erie basin contains about 18 percent of the capacity equipped to meet the 1 mg/L objective. On this ratio basis first costs for Lake Erie were about \$3.6 million (\$2.7 million capital, \$0.9 development) in 1973 dollars.

The calculation of incremental operating and maintenance and chemical costs is a little more difficult. While MOE publishes costs of operating each plant in the Province on an annual basis, it was not possible to evaluate this information on a timely enough basis for this writing. It might be possible to separate out the actual incremental costs associated with phosphorus removal from 1974 to the present, at some time in the future.

TABLE 10

FUNDS COMMITTED FOR MUNICIPAL SEWERAGE CONSTRUCTION
IN THE GREAT LAKES BASIN
(in millions of dollars)

YEAR	CAPITAL COMMITMENTS FOR SEWERAGE WORKS IN ONTARIO BY ALL LEVELS OF GOVERNMENT ¹	OBLIGATED STATE AND FEDERAL FUNDS IN THE UNITED STATES ²
1971	57	370
1972	66	313
1973	138	419
1974	103	509
1975	112	950
1976	174	429
1977	150	716
1978	191	618
1979	200	456
TOTAL	1,191	4,780

¹ Figures represent total capital commitments for treatment plants and interceptor sewers.

² Figures represent total United States eligible project costs with federal grant approval through December 31, 1979.

Source: Great Lakes Water Quality Board Annual Report: 1980

Drynan (1978) developed computer simulated estimates of process capital costs and operation and maintenance costs related to various effluent concentrations of total phosphorus. These estimates were done for selected treatment plants in the Lake Erie and Lake Ontario basins. It is noted that while these costs are generated by an engineering model, they appear to be realistic on a comparative basis with available data on actual cost experience on a basin wide basis. Three plants in the Lake Erie basin were included in the analysis: Sarnia; Windsor - Little River; and Windsor - Westerly; with 1975 serviced populations (design capacities) of 65,000 (17.4 MGD), 60,000 (14.4 MGD), and 160,000 (28.8 MGD) respectively. Unfortunately, these data do not agree with those available in other sources, however, for our purposes the differences are not really significant. Table 11 contains cost estimates (in 1975 dollars), cumulated for the 1975-2000 period, for various levels of phosphorus effluent limitations (Drynan, 1978). The bracketted numbers are my estimate of basin-wide costs (all plants).

According to Drynan's data, these plants service 285,000 people in total and have a design capacity of 60.6 MGD. Depending on data source, this is roughly 37.5 percent of basin design capacity and 65.4 percent of basin serviced population. Precision in these estimates is not really vital; the 'rough' connotes the questionable accuracy of the numbers. Extrapolating the Drynan data in Table 11 to an approximate total basin serviced population, yields the bracketted estimates. These estimates imply that the achievement of the 1.0 mg/L objective over the entire Lake Erie basin has an incremental capital cost of \$3.7 million over 25 years.

TABLE 11 *

COMPUTER SIMULATED MUNICIPAL WASTEWATER TREATMENT PLANT COSTS OVER A 25
YEAR PERIOD (1975-2000) FOR SELECTED PLANTS IN LAKE ERIE DRAINAGE BASIN

Phosphorus Effluent Limitation (mg/L)	Number of Plants	Simulated Wastewater Treatment Plant Costs (Millions of 1975 Dollars)		
		Capital	O&M	Total
None	3	13.1 (20.0)	30.2 (46.2)	43.3 (66.2)
1.0	3	15.5 (23.7)	56.3 (86.1)	71.8 (109.8)
0.5	3	24.8 (37.9)	69.6 (106.5)	94.4 (144.4)
0.3	3	36.2 (55.4)	186.0 (184.6)	222.0 (339.6)
0.1	3	34.9 (53.4)	216.1 (330.6)	251.0 (384.0)

* Source: Drynan (1978).

Some perspective needs to be put on such numbers. Drynan acknowledges the large error potential inherent in extrapolating these data to particular plants or municipalities. Taken as a whole, his analysis indicated that for Lakes Erie and Ontario total populations, the cumulative incremental capital cost of phosphorus removal was \$100 million. In other words, this is the total amortized cost over 25 years, at 10 percent interest, of doing all the work in the first year (1975) by spending about \$9.2 million. This is something less than the \$15 million total capital cost that was actually incurred for the entire Great Lakes basin, but considering the coverage and time period of expenditure, it is reasonably close. Taking the estimate of actual outlays of \$2.7 million capital for Lake Erie, and ignoring population growth, this results in a cumulative cost, comparable to those in Table 11, of about \$7.4 million. This is twice as high as Drynan's figure, however, both are subject to imprecision due to potential extrapolation errors. The actual estimate based on MOE data is particularly vulnerable because unlike the Drynan data, no plant specific information was available on which to base what was required to reach the 1.0 mg/L objective. The Lake Erie plants could have involved lower than average costs. Such a situation may very well be what the Drynan data is telling us.

The whole point of this somewhat convoluted effort was to try to get some overall idea of how the limited amounts of available data on actual and simulated capital costs of phosphorus removal compare and what their magnitudes are. In summary, it seems clear that the incremental capital costs, both past and likely future, are relatively insignificant compared to total outlays for sewage treatment systems. Taking the estimate based on MOE actual outlays, and putting it in terms comparable

with Drynan gives us a range of capital costs of between \$150,000 and \$300,000 per year for 25 years. It is important to note that there are substantial differences in concept and background between these sets of numbers, and direct, totally consistent and meaningful comparisons are not possible. Nonetheless, it is felt that any errors we expose ourselves to are more than compensated for by the knowledge we glean, since the numbers are really not large enough to get too excited about.

The estimates of operating and maintenance costs are very possibly subject to the same kinds of errors. From Table 11, we can see that on a total population basis, the cumulative incremental cost of achieving the 1.0 mg/L objective is almost \$40 million. This is an average annual cost of slightly less than \$1.6 million. Drynan reported on observed errors between simulated and actual O&M costs ranging from minus 23 percent to up to plus 50 percent, however, only in one case was simulated greater than reported. It follows that a range of \$1.6 million to \$2.4 million per year should cover the operating and maintenance component of the 1.0 mg/L objective for Lake Erie.

In summary, the likely range of annual costs to achieve the 1.0 mg/L objective appears to be about \$1.75 million to \$2.7 million in approximate 1975 dollars. I say "approximate" because the capital costs had already been incurred by 1973, so bringing them up to 1975 terms would make them smaller. On the other hand, the O&M costs are incurred every year, so the most current date would be more reflective of actuality.

IV PHOSPHORUS MANAGEMENT STRATEGIES - PAST AND PRESENT

To date, phosphorus removal at municipal wastewater treatment plants and controlling the phosphate content of detergents have formed the primary emphasis of control strategies. Progress made by these programs has been well documented in annual reports to the IJC from the Great Lakes Water Quality Board as well as in numerous other studies carried out both regularly and intermittently.

Based on estimates taken from the Phosphorus Management Strategies Task Force Report (PMSTF) (1980), and the Great Lakes Water Quality Board Report (1980), the loadings in Table 7 reflect the status of Lake Erie programs. Due to revisions and reporting dates, there is no strict consistency between the data contained in the PMSTF report and the Water Quality Board Report. Since all are subject to estimation errors, we need not be too concerned. For our purposes, the Board estimates will be used to illustrate progress made and the PMSTF data will provide benchmarks from which to consider future actions. From this data we can see clearly that Canadian loadings to Lake Erie have been within 1972 Agreement objectives since 1975, with only slight discrepancies. As of 1979, U.S. loadings required a further reduction of about 1802 t/yr to achieve those objectives.

While these data reflect significantly large loading reductions, reports of concomitant changes in water quality indicators such as total phosphorus, chlorophyll, oxygen depletion and changes in zoo-benthos are not so visibly dramatic. This is partly related to the timeliness of the lake status evaluations and the long time period over which loadings

reductions were staged. However viewed, hitherto observed changes in the usual quality indicators are not of the same magnitude as the loadings changes, nor should one expect them to be. The EPA report of July, 1980, on the Lake Erie Nutrient Control Program presents the results of a comprehensive three-year assessment of nutrient control efforts. It was reported that;

"the fundamental conclusion of this assessment was that up until 1975 no significant decrease in the loadings of nutrients had taken place. Therefore, during this period the concentrations and quantities of nutrients within the waters of the lake have remained relatively stable. An encouraging sign of nutrient control is that although no decreases have been observed, the constant increases which have taken place in preceding decades have been stopped. Other indicators of eutrophication, such as hypolimnetic oxygen depletion rates, chlorophyll concentrations, methane production, plankton and benthos populations, dissolved solids and turbidity, have remained high since 1970, but also relatively stable."

The report also confirmed the findings of Project Hypo (Burns and Ross, 1972) that under anoxic conditions, the central basin sediments become a source of phosphorus rather than a sink at a critical period in the annual lake cycle. Moreover, storm resuspension of sediment can have an even larger impact on internal nutrient loading, particularly during non-stratified periods. It was observed that this and other meteorological variations can have a profound effect on lake trophic status. Table 8 contains estimates of the areal extent of central basin hypolimnetic anoxia during the period 1930-1975. This shows clearly the radical impact on this variable of the particular wind climate that occurred during thermocline formation in 1975. In addition, Table 9 contains data from that same report showing the trends in net oxygen

TABLE 7
ESTIMATED TOTAL PHOSPHORUS LOADINGS TO LAKE ERIE
(metric tons/yr)

	1968	1972	1975	1976	1977	1978	1979	Load at 1 mg/L (1979 flow)
	(No Programs)	(Par. 1972 Agree.)						
<u>TOTAL LOAD</u>								
(U.S. and CANADA)	30000*			18425*			19463	
<u>MUNICIPAL</u>								
TOTAL	18200*	15257	7950	6778	6757	5835	4336	2534
CANADA		1387	219	252	250	222	214	234
U.S.		13870	7731	6526	6507	5614	4122	2300

* SOURCE: Phosphorus Management Strategies Task Force.

demand of the central and eastern basin hypolimnions of Lake Erie up to 1975. More recently, Burns and Rosa (1979), report on summer oxygen and phosphorus data for Lake Erie for the years 1970, 1977, and 1978. They observed that phosphorus regeneration in the central basin hypolimnion varied in intensity during the three summers. In 1970, this regeneration increased the hypolimnion total phosphorus concentration to 110.0 ug/L, while much less was regenerated in 1977 and very little in 1978. During 1977 and 1978, the anoxic area was fairly small, located in a small pocket close to the north shore. These overall improvements were accompanied in 1978 by total phosphorus concentrations in the anoxic area averaging about 20 ug/L. They concluded that the oxygen depletion rates between 1970 and 1978 showed no change and the central basin mean total phosphorus trend shows a decrease although the difference is not statistically significant. The IJC Seventh Annual Report on Great Lakes Water Quality (1980), noted that preliminary results of a two-year extensive surveillance effort on Lake Erie, begun in 1978, indicated little change in phosphorus concentrations since 1970.

From another perspective the Water Quality Board Annual Report (1980) noted that between 1967 and 1977, total phosphorus levels in the vicinity of Colchester Beach and Point Pelee declined from 46 ug/L to under 30 ug/L, with a similar decline observed at the Kingsville water intake. These results were thought to be related to decreased loads from the Detroit River. Studies in the western basin showed notable improvements in the composition of benthic communities between 1967 and 1979. Particularly notable was the reappearance for the first time since

TABLE 8

ESTIMATED AREA OF THE ANOXIC HYPOLIMNION OF
THE CENTRAL BASIN OF LAKE ERIE 1930-1974

YEAR	AREA (km ²)	<u>PERCENT OF CENTRAL BASIN</u>	
		Hypolimnion	Total
1930	300	3.0	1.9
1959	3,600	33.0	22.3
1960	1,660	15.0	10.3
1961	3,640	33.0	22.5
1964	5,870	53.0	36.3
1967	7,500	68.0	46.4
1970	6,600	60.0	40.4
1972	7,970	72.5	49.3
1973	11,270	93.7	69.8
1974	10,250	87.0	63.4
1975	400	3.4	2.5

SOURCE: Lake Erie Nutrient Control Program. E.P.A. July, 1980.

TABLE 9

TRENDS IN NET OXYGEN DEMAND OF THE CENTRAL
AND EASTERN BASIN HYPOLIMNIONS OF LAKE ERIE

YEAR	NET OXYGEN DEMAND			
	Rate Per Unit Area (mg O ₂ cm ⁻² day ⁻¹)		Rate Per Unit Volume (mg O ₂ l ⁻¹ day ⁻¹)	
	CENTRAL BASIN	EASTERN BASIN	CENTRAL BASIN	EASTERN BASIN
1930	0.008	-	0.054	-
1940	0.015	-	0.067	-
1950	0.025	-	0.070	-
1960	0.037	-	0.093	-
1970	0.039	-	0.13	-
1973	0.053	0.023	0.12	0.012
1974	0.060	0.095	0.13	0.040
1975	0.067	0.076	0.10	0.040

SOURCE: Lake Erie Nutrient Control Program. E.P.A. July, 1980.

the early 1950's of the burrowing mayfly (Hexajenia Limbata), near the mouth of the Detroit River. In the same general area, fish spawning occurrences have been reported as well.

More recent data for 1979 to 1981 is very sparse. Hypolimnetic cruises were not funded in Canada. The U.S. Environmental Protection Agency did Lake Erie in 1979, but water quality analysis problems put the quality of the results in doubt. In 1980, responsibility was given to CLEAR of Ohio State. To date, the phosphorus regeneration has not been worked out, but there was apparently very little anoxia (Rosa, pers. comm.).

The significance of this limited example of surveillance results is somewhat overshadowed by changing concerns and priorities of overall Great Lakes management. It is also subject to a good deal of debate internal to the phosphorus problem itself. This debate chiefly concerns the viability of the oxygen and algae objectives in the 1978 revision of the Great Lakes Agreement, and the programs and target loads developed in pursuit of these objectives. Therefore, discussion of the surveillance results cannot be done meaningfully in isolation. Such results have in effect had their importance preempted.

The Canada - U.S. Agreement on Great Lakes Water Quality of 1978 revised its 1972 recommendations concerning programs and goals regarding phosphorus control and desired water quality conditions. The oxygen and algae objectives were specified for Lake Erie, and phosphorus loadings targets were set (for each lake). It was recommended that municipal waste treatment facilities in the basin of Lake Erie (Ontario) achieve

effluent concentrations of 0.5 mg/L total phosphorus. Also recommended was the development of programs to reduce the loadings of phosphorus into Lake Erie (Ontario) from diffuse sources by 30 percent. Further programs to reduce the loadings from industrial sources, and to reduce household detergent phosphorus content to 0.5 percent were also mentioned.

These recommendations and underlying goals have generated many questions from several sources. Several points concerning the adequacy of the oxygen objective have been raised above, particularly as regards the nature and location of human influence on, and uses of, the lake resource. Given the present status of programs already underway and the uncertainty regarding the nature and measurability of the whole lake response, it is legitimate to question the implementation of further across-the-board loadings reduction programs. The recommendations of the PMSTF report represent a common sense approach to a policy situation that is still very much in a transition stage. Quite frankly, it must be recognized that there is a great deal of uncertainty in our understanding of lake response characteristics. Before embarking on ambitious new programs, surely we should tie up the loose ends of existing ones, and ensure that we get the maximum impact of original intentions.

The evolving and uncertain nature of the policy/program situation is derived in good measure from the presently ongoing scientific debate over the oxygen objective. This objective reflected, at least in part, a generally held conclusion that hypolimnetic anoxia was fundamentally attributable to cultural eutrophication. It was observed that anoxic conditions in Lake Erie resulted in regeneration rates of sedimented phosphorus that were substantially in excess of those

observed under oxic conditions (Burns and Ross, 1972). Charlton (1980) challenged the eutrophication relationship and argued that available oxygen data did not indicate a clear correlation with trophic changes which have occurred elsewhere in the lake. He concluded that there has been little change in oxygen depletion rates for the last 20, possibly 30 years and that little reason exists to expect any large changes in the immediate future. He thus challenged the achievability of the oxygen objective. Lee and Jones (1979b) simulated alternative loading reductions and selected oxygen objectives using generally accepted models. They report that in order to achieve dissolved oxygen concentrations greater than zero on a consistent year-to-year basis, modelled results indicate that phosphorus loadings would have to be reduced to about 2500 - 6500 metric tons per year. This compares to the target load of 11,000 metric tons. Similarly, these models indicate that the maintenance of 4 mg/L dissolved oxygen in the hypolimnion, would require a maximum load of about 500 to 2000 metric tons. One significance of this last result relates to the possibility of rehabilitating preferred salmonid species. Ministry of Natural Resources (1977) studies indicate that required oxygen concentrations for lake trout, for example, can be as low as 4.0 mg/L, but preferred or optimal levels are in the 5 to 6 mg/L range. While Lee and Jones note some literature suggestive of modifications to this general result and related to enhanced hypolimnetic oxygen regeneration possibilities at target load levels, they conclude that such impacts are unlikely to significantly alter their basic conclusions. Other questions concerning the implications of their results for the more complex questions concerning diffuse source loading reduction requirements, and bioavailability,

are also examined. They conclude that the Lake Erie target loads and inherent strategies need a close reexamination particularly as regards the rationale on which they are based.

All of this argument is fine as far as it goes, but before we make fundamental conclusions we should remember that all such arguments are inconclusive and still under debate. As noted earlier, Burns and Rosa (forthcoming) are preparing new evidence that suggests that there has been an observable change in oxygen depletion in Lake Erie, thus lending support to the oxygen objective. There are clearly a number of important questions of fact and methodology that remain.

In this regard it appears useful to recall our earlier discussion concerning Georgescu - Roegen's (1971) contribution to our understanding of laws involving variables that are not immediately connected - as cause and effect in the strictest sense of the terms - and laws involving variables that are quantified qualities. In both cases we can generally expect that the formulae of such laws will be non-proportional and non-linear. Moreover, most quality - related phenomena have a sort of climax followed by a rapid breakdown. On this basis, it seems reasonable to argue that measures of oxygen concentration, depletion and other related variables fall into this general categorization. Being interpreted as measures of water quality, they are quantified qualities. Involving complex physical, chemical, and biological processes, they are not directly causal related. One would therefore appear to be justified in expecting laws involving such variables to exhibit the properties noted above.

The phosphorus loadings - oxygen depletion/concentration phenomena appears to fit this mold classically. It follows then, that the extent to which the models used by Lee and Jones (1979b), and others, fail to recognize and capture these fundamental properties, they are inadequate representations of the phenomena they purport to describe. For example, how does one model the climactic response of sediment phosphorus regeneration to anoxic conditions? Furthermore, how do we definitize the resultant impacts on water column phosphorus concentrations during fall turnover, and on fall algae blooms that will ultimately feedback and exacerbate the oxygen problem? Extending the argument further, how does one model the reverse process; the climactic reduction in regeneration due to the achievement of oxic conditions, and the resultant interrelated phenomena as above? Just because the analytical representations of eutrophication processes are indifferent to the direction in which they are numerically solved does not mean that actual phenomena display the same characteristic. While the trophic status (however defined) of Lake Erie might reach a state attained previously, it does not follow that it will do so by retracing its original course phase by phase in the reverse order. Only mechanical laws are absolutely reversible in this sense. It therefore behooves us to make a clear distinction between mechanical analogues of natural processes and those processes themselves. The main point being that the existence of complex quality - related processes, novelty, and general irreversibility make it likely that the effects of each policy experiment will only be known after we observe what we would like to predict.

To put this into a policy perspective I would suggest that the original insights contained in Project Hypo have not been given adequate time to prove or disprove their significance. The loadings reductions scheduled under the 1972 Agreement have not yet been fully achieved. In fact, the surveillance data given above indicate clearly that the first significant reductions did not occur until after 1975. Since man's entire history in the basin has been a source of multiple stresses on Lake Erie, by what miracle do we expect to reverse the process in a few years? From a realistic perspective the surveillance data presented earlier provide some evidence of desirable changes in water quality indicators. It appears that we are moving towards a situation where anoxia induced regeneration is lessening even though target loads and waste treatment effluent limitations under the 1972 Agreement are not being entirely met. At bottom, it can be argued that while physical processes are important, the viability of man-controllable stress reductions, like phosphorus management, and not just the oxygen objective, will not be tested until the vicious circle involved in the anoxia/regeneration phenomenon is either broken or observed to be beyond man's control. Like all vicious circles, the present one requires patience and perseverance directed at the deadlock or climax aspects of the interacting process. Based on what we know and can reasonably surmise, once the vicious circle of anoxic conditions feeding on and perpetuating themselves is broken, it seems plausible that a climactic decrease in internal loadings will occur, followed by relatively dramatic impacts on related phenomena and cumulative impacts on related water quality. As already noted, such a course of events already seems to be underway. What is needed is the patience to see this process through to its ultimate end. In this regard, it is helpful if we recognize that the

process of change in question is not determined by the passage of clock time but by a sequence of events that endure in overlapping succession. The event, oxic hypolimnion, has to occur and endure before the other related events can occur and endure. Therefore, we cannot realistically expect identifiable results to obligingly appear in a rhythm that corresponds to our institutional need for annual justification of program funding.

On the other hand, Charlton and the others might very well be correct. Nonetheless, I would argue that the data and models underlying their arguments do not possess sufficient reliability and inferential power to support definitive and highly significant decisions of policy. If we are truly committed to a meaningful policy of phosphorus management then we are going to have to realize that there is no magic black - box to guide our every move with great precision. If there was, the 'problem' would vanish, and we would not be needed.

After all these arguments are made, it still remains that we cannot know the results of our programs until we observe them. Fortunately, the program itself can be viewed as a multi-faceted Whole. Therefore, there is absolutely no need to restrict our total focus to uncertain, slow-responding whole lake quality indicators. We can do so, if we choose to mistakenly identify the whole policy - program mix with one of the parts. However, such a choice should be recognized as a form of self-imposed blinkers. Just as the ecosystem must be viewed as a whole, so must the broad spectrum of program potentials be viewed. The name of the game is 'perspective'. We have enough constraints on our actions inherent in the natural systems involved without blindly turning objectives into more constraints.

The objectives contained in the 1978 Agreement relate to the policy - program Whole. Since the U.S. was and still is the major source of phosphorus loadings to Lake Erie, Canada, by itself, can do little to improve the water quality on a whole lake basis. It follows then, that the whole lake goals forming the core of the 1978 Agreement are essential and in our own interest. Only by reducing U.S. loadings do we have a chance of achieving maximum whole lake related benefit ourselves. We had better be careful not to let loose thinking obscure this basic reality. It is essential to understand that the objectives in the Agreement obtain their meaning and clarity only because they relate to emergent or integrative properties of the Whole to which they pertain. Otherwise, there would exist no common, unifying purpose that the parts of the whole could unambiguously relate to and build towards. Unless there are more suitable objectives readily available we would be best not to tinker unnecessarily.

It should be clear that only in decisions relating to the Whole is it necessary to ultimately abstract from the parts. Having made decisions at that level, we are then free to view program formulation at any level that it is meaningful for that exercise. This of necessity involves splitting the whole into parts and in this regard there is no inherent limit to the potential division. We are therefore not constrained in the ways that we can relate specific programs to the overall objectives. Again, it is a matter of perspective. The more ways we look at something, the more we learn about it. Through this purposive, sorting process we will find specific program formulations that are somehow better.

Taking all of the above into consideration, together with some economizing principles, we can outline some general guidelines for future policy. It is widely recognized that pollution loadings vary spatially, temporally, and in terms of their impact on ambient ecosystem quality. It is fundamental that policies not recognizing these factors do not generally achieve the least-cost-maximum benefit result. For example, uniform standards, such as those suggested by the 1978 Agreement, require that each source reduce loadings by the same proportion, regardless of unit cost or resultant benefits. Further, reasonable policies should recognize that first-order negative effects of pollution loadings are often more related to resultant concentration measures (ambient quality) which also vary by location and time (Gregor and Rast, 1980) than to the loadings themselves. It follows that policies taking these points into consideration are more likely to exhibit properties of allocative efficiency than those that focus only on loadings, regardless of source or receptor properties. In terms of phosphorus management policy, this supports the views of Gregor and Wagner (1980), Johnson et al., (1980) and Johnson (1980). Specifically, that efficient policies should consider each source separately and select areas that present significant problems; and since impacts on human uses are overwhelmingly in the littoral zone, that nearshore problem areas should form another policy focus. In other words, policy dollars should not be distributed uniformly, but sequentially, concentrating initially in those areas that exhibit the highest return per dollar spent.

Johnson et al., (1980) developed a model describing current and projected phosphorus and sediment loadings to the lower lakes under selected management strategies applied to point and non-point sources.

Using cost data derived from Drynan (1978) (the same data we considered earlier) and other sources, they examined possible cost scenarios involved in various source specific phosphorus reduction programs. Table 12 is a reproduction of the overall results of their analysis for Lake Erie. Explanations of the nonpoint source program packages are contained in the original text, however, from the perspective that we will consider this data, such information is not significant. Several important factors stand out.

First, further reductions in loadings, from whatever source, are going to cost progressively more than previous reductions as we exhaust the more easily dealt with point sources. The cost per metric ton column illustrates this forcefully. Particularly significant is the inherent uncertainty involved in the whole issue of rural nonpoint source programs. Getting widespread acceptance of the changes involved in such a program is going to be difficult, no matter how easy it might appear on paper. Without going into details of specific loading reduction needs it appears that even minimal further reductions could involve costs of more than \$20 million per annum for Canada alone. This is about ten times the costs approximated to date. Secondly, as noted earlier, the U.S. is the major source of phosphorus loadings to Lake Erie. This is once again indicated by the data in Table 12. Finally, further loadings reductions of any substantive amount are going to entail a mix of programs. In this scenario we are going to come up against our old adversary again; qualitative variation that defies totally quantitative and logical understanding. In such a situation, neither the overall program impacts nor associated costs are going to be easy to predict accurately since we are moving out of the realm of a tried and proven technical fix. Of

particular import in this regard is how we choose to view the implementation of programs to abate rural non-point loadings. The necessity of such programs is based on considerations that go far beyond those related solely to phosphorus as a pollutant. It is one of the hard facts of economic life that man's entire societal process is completely and irrevocably tributary to the agricultural resource base. Unfortunately, the abundance provided by the mechanization and energy related transformation of agriculture has blinded us to a well recognized and documented, insidious degradation of the resource base. This degradation is an emergent property of the totality of the current agricultural ecosystem. The brutal truth is that our food production potential is in substantial jeopardy under existing practices, attitudes and policies. The specifics of the problem and recommendations for policy are well documented and extensively discussed in the literature, including; Rifkin (1980), Bromfield (1947), Clark (1975), Brubaker (1972), Commoner (1971), Davis (1977), Pimental et al (1976), Carter (1977), Pfeiffer (1976), Jorling (1978), Latornell (1978), Thomas (1978), Cory and Timmons (1978), Russel (1968), Jones (1979), McEwen (1978), Pimental at al (1978), Council on Environmental Quality (1979), and Van Vliet et al (1976). Even a cursory review of this work shows clearly that soil erosion is one of the most insidious factors at work in the ongoing destructive process. Specific discussions of the extent of the erosion problem, ecosystem impacts (including water quality) and policy recommendations are also presented in Shear and Watson, eds, (1977), Monteith et al (1981), Philips et al (1980), Porcella and Bishop (1975), Johnson et al (1980), Leopold (1966), Cowden (1976), as well as numerous reports from PLUARG and other sources.

TABLE 12

PHOSPHORUS REDUCTION PROGRAMS APPLICABLE TO LAKE ERIE

Remedial Measure Target Source and Strategy	Estimated Phosphorus Reduction (tonnes)	Estimated Additional Annual Cost (\$million)	Estimated Annual Cost-effectiveness (\$thousand/tonne Reduction)
Urban point sources:			
a) from 1 ppm 1975 load level to 0.5 ppm in 1980	U.S. Canada Total	1,180 125 1,305	9.0 1.5 10.5
			8
b) from 0.5 ppm to 0.3 ppm in 1980	U.S. Canada Total	580 65 645	54.5 6.5 61.0
			95
Rural nonpoint sources:			
Level 1* (10 percent reduction)	U.S. Canada	350 100 450	minimal minimal
			minimal
Level 2* (cumulative 25 percent reduction)	U.S. Canada Total	200 150 350	12.5 10.0 22.5
			64
Level 3* (cumulative 40 percent reduction)	U.S. Canada Total	180 125 305	32.5 20.5 53.0
			174
Urban nonpoint sources:			
Level 1*	U.S. Canada Total	425 20 445	34.0 2.5 36.5
			82
Level 2*	U.S. Canada Total	575 40 615	89.5 7.0 96.5
			157

*Program packages are explained in original source.
Source: Johnson et al 1980.

Taken together, these investigations provide overwhelming evidence that our present agricultural system is on a persistent and cumulative course towards eventual disaster. While all of the discussion is not directly related to the Great Lakes basin, the general focus of the evidence is widely applicable and fits those analyses specific to the basin. The trends are clear and supported by factual observation and generally held conceptual understanding. Clearly, the rationale for soil erosion remedial measures goes to the very core of the societal Whole, far beyond the narrower issue of water quality. So too, the benefits of such measures will extend far beyond the boundaries of the aquatic ecosystem. The basic outline of such programs already exists. What is needed is an extension of this thinking to include the spatial and temporal dimensions of the underlying phenomena and the expanded vision that an ecosystem perspective provides.

V COSTS VERSUS BENEFITS - DISCUSSION, CRITIQUE AND ALTERNATIVES

In broad overview, Table 13 indicates a substantial potential for phosphorus related disruption of human uses of the Lake Erie resource. It is important to stress once again that these estimates do not relate to the consequences of a "do nothing" policy on phosphorus management that would lead to gross water quality deterioration. The impacts of such a stance would go far beyond anything that could be meaningfully measured based on what we now know. Rather, these figures should be viewed as a reflection of possible dollar valuations based on a middle range of water quality. Furthermore, these figures are meant to serve primarily an illustrative and comparative purpose as they were generated from a purposefully wide-ranging discussion of the nature of the problem. I disclaim their 'truth content' since there is always the danger that such numbers become viewed as being cast in stone due to a general addiction in such matters to numbers, any numbers. Unfortunately, such an obsession with measure more often than not results in a total loss of contact with what is really being measured.

This obsession is reflected by the standard practice in program evaluation of performing some kind of ritual benefit-cost calculus on such figures. This common procedure arises mainly from the utterly mistaken belief that benefit-cost analysis will somehow prevent the misallocation or inefficient expenditure of public funds. Certainly, the economical management of resources is and always will be a matter of serious concern for society. Unfortunately, benefit-cost techniques, and the standard theoretical framework from which they are drawn, are grossly inadequate

TABLE 13

SUMMARY OF DAMAGE VALUATIONS

USE	MINIMUM VALUATION OF DAMAGES		
	<u>Measured</u> \$/yr	<u>Measured</u>	<u>Potential</u>
		Lump Sum \$	
Municipal Water Supplies			
- Add-on technology	937,000	-	-
- Capacity Loss	140,000	-	-
- Location decisions	n/a	n/a	Greater than \$1,000,000 lump sum
Industrial Water Users	n/a	n/a	Yes
Hydro Electric Power Generation	n/a	n/a	Yes
Property Values	-	18-36 million	-
Commercial Fishing	13 million	14 million	-
- Employment	-	700 jobs	300-400 jobs
Water Based Outdoor Recreation	73-82 million	-	Large-scale industry disruption
n/a - not available			

to the task of providing an objective, value-free, scientific basis for such an ideal. Pearce (1976) presents arguments showing the limited conceptual relevance of the benefit-cost technique. This approach has direct relevance only in the case of "nuisance" pollutants, such as waste bottles or cans, which do not have sustained ecological effects. For persistent, or cumulative, or stock pollutants such as cadmium, mercury, lead, mirex, dioxin, and so on, the benefit-cost approach appears positively irrelevant

and very likely ecologically perverse. The perversity arises because the so-called "optimal" levels of abatement derived from standard approaches will always justify additions to the stock of these pollutants. In other words, the usual policy prescription that emerges is to continue a positive flow of these pollutants into the environment. The case where conventional pollutants involve dynamic ecological effects is the most interesting. The standard optimal correction will not prevent a continued degradation of the environment since, except by pure chance, it will always dictate pollutant loadings above ecological carrying capacity. So in those cases where carrying capacity is degraded by being continually exceeded, the benefit-cost approach will not prevent increasing ecological instability. Such instability, if continued, can end only by total destruction of the environment's assimilative capacity. Benefit-cost analysis therefore fails to acknowledge the impact of any apparent optimum on ecological stability. He concludes that where biologically harmful pollutants cumulate or where ecological instability pertains, benefit-cost should give way to standard setting based on physical information related to 'ecological optimum' objectives and assimilative capacity constraints.

Other authors, including Chipman and Moore (1976), Oelschlager (1979), Junger (1979), Baram (1980), and Alston (1980), present broadly based and consistent critiques of various aspects of benefit-cost analysis and its theoretical foundation, Paretian welfare economics. It is not possible to fully describe the depth and richness of their critiques here except to emphasize that their conclusions do not reflect anything radical, or the observation that standard analysis is somehow wrong. To the contrary,

their conclusions are based on the rationale and internal logic of the standard analysis itself. Nevertheless - and this is a most remarkable fact - such observations have never been squarely met by defenders of welfare economics and benefit-cost analysis, but have for the most part been evaded or entirely ignored, (Chipman and Moore 1976, p. 69; Alston 1980, p. 49).

Their observations and conclusions reflect numerous demonstrable facts that illustrate the general inadequacy and irrelevancy of standard economics and benefit-cost analysis as policy evaluation tools. Properly qualified, it is clear that benefit-cost techniques have only limited cognitive value. Looked at realistically, does anyone really believe that society consists solely of a fused collection of utilitarian, individualistic personae devoid of envy and altruism, love and hate, with fixed and identical tastes and preferences? Further, who would argue that the real economy is characterized by atomistic, perfectly knowledgeable, perfectly mobile price-taking actors operating in a frictionless, private-goods only, pollution free, power free, profit free, perfectly competitive market, where all people are treated "equally" and there are no class conflicts? A world where everybody is a nobody, and there is no scope for economic conflict between the individual and society as a whole; a society that does not exist apart from the individuals and where the concept of the public interest is a myth. These points should be thoughtfully considered, because it is from this gross caricature of the capitalist society we live in that the prescription of allocative efficiency is directly derived and dependent.

Furthermore, such efficiency cannot be viewed independently from the distribution of human and property resources and power, and society's views on the desirability of that distribution. It can be clearly seen then that an objective, value-free economics is nothing but an illusion. It follows that the efficiency calculations contained in benefit-cost analysis are not the application of ideologically free science, but the ideology of the status quo (Alston 1980, p. 48). Moreover, the reduction of all policy considerations into money through the use of prices generated in the market is also ideological. This pertains because there are an infinite number of price outcomes, each a function of a different distribution of income, property and resources within society. Therefore, a society that makes policy decisions using analytical guides that are based on an undesirable distribution of property rights - to the environment, for example - is going to make decisions that it will consider undesirable.

Benefit-cost techniques cannot deal with cultural change. Even if we selfishly disregard future generations, which standard analysis does explicitly, future changes in the tastes of the living cannot be captured. This is particularly alarming for environmental policy contexts, since such policies are always concerned with the future. As Hotelling (1931) pointed out once and for all long ago, one can only discuss the optimum allocation of resources when the demand over the entire future is known. Another major objection turns around the fact that many benefits and costs cannot be assigned a monetary value except in an entirely arbitrary way. How much would you sell your life for; or your health? What is the price of the Great Lakes? The changing, qualitative essence of nature we discussed

earlier makes environmental effects impossible to prophesy except perhaps in broad outline. Yet it is precisely such effects that are not predictable that cannot be considered in benefit-cost analysis. The inability of such techniques to adequately address the question of value, or to account for the essentially qualitative nature of man and his environment portends dangerous consequences. By following such incomplete guides society may very well destroy or impair many things of great value.

Perhaps the simplest and most devastating indictment of the uncritical application of efficiency criteria is derived directly from the internal logic of the standard model. The theory of second-best, generalized by Lipsey and Lancaster (1956), essentially argues that if the efficiency conditions generated by the Pareto optimum are not satisfied everywhere in the real world, then pursuing efficiency in any one particular instance will not necessarily, and likely will not, result in an overall societal improvement. In other words, given our own highly imperfect world, there is no a priori reason to blindly pursue efficiency in deciding whether to adopt specific social or environmental policies. The belief that it is better to fulfill the efficiency conditions in some instances rather than none is false (Winch 1971, p. 110-111). On this point, Alston (1980, p. 71) notes a comment by Lancaster to the effect that; the theory "...really amounts to noting that optimality is a general equilibrium property of the economy as a whole and that the appropriate rules for one sector thus depend on the actual behaviour in all others". Is this not just another way of expressing the ecosystem approach? Not only will piecemeal approaches not work, they have no scientific basis for real world applications and never have had.

At bottom then, it must be understood that there are not, and never have been, any simple a priori or technical rules to guide policy decisions. Such mistaken beliefs, embodied in efficiency criteria for example, can lead to some paradoxical results if followed blindly. If we perceive that some policy is required but on the basis of standard analysis reject such a policy as inefficient, then we are led to the illogical position that where we are must be the best of all possible worlds! (Alston 1980, p. 50). In other words, if for some reason we "feel" that the existing situation is not satisfactory, pursuing policies guided by efficiency considerations might very well tell us that our feelings are wrong and that we really want to be where we are. Put another way, if we know we want to move in a certain direction but are uncertain as to how to go about it in the best way, it does not follow that settling for Paretian optimality or efficient change is better than an inefficient change. It should be clear then that fundamental social policies that involve choices for change, like environmental conservation, are issues that transcend and are quite distinct from considerations of how to affect such change in the most efficient way. Simply put, efficiency criteria are useful only as guides in assessing the "how" of policy, not as rules governing the "should".

This critique of standard economic evaluation criteria reflects nothing more than the general malaise that affects virtually the entire edifice of mainstream economics. The worldwide fiasco in the monetary and financial domain is well-known. The brutal truth is that the static, ahistorical and mechanistic nature and grounding of standard economic theory bears no relationship whatsoever to the dynamic, evolving and organic nature

of the real world. A meaningful understanding of real world problems will require the setting aside of commonly held preconceived notions derived from the wholly imaginary abstraction that constitutes standard theory.

VI MAN-ECONOMY-ENVIRONMENT: AN EMERGING VIEW

The standard representation of the economic process that appears in most introductory textbooks portrays it as an isolated, self-sustaining merry-go-round between 'production' and 'consumption'. In such a portrayal, the only thing that matters is money and the name of the game is to lay claim to as much of that money as possible. The essentially neo-classical ancestry of standard economics emerged during the heyday of the mechanistic dogma. This dogma fascinated philosophers and natural scientists for centuries. It culminated in what has come to be known as the mechanical world paradigm. Rifkin (1980, p. 28-29) describes the impact of this paradigm on economic thinking that is still with us today.

"Believing that men and women are basically egoists in pursuit of economic gain, Smith's theories subordinate all human desires to the quest for material abundance to satisfy physical needs. There are no ethical choices to be made, only utilitarian judgements exercised by each individual pursuing self-interest.

Bacon, Descartes, Newton, Locke, and Smith were the great popularizers of the mechanical world view. Many others preceded and followed them. Still, their basic assumptions remain with us today. Those assumptions can be summarized in a few short sentences. First, there is a precise mathematical order to the universe that can be deduced from an examination of the motions of the heavenly bodies. Unfortunately, here on earth most things in the primal state are in a chaotic and confused condition. Therefore, things need to be rearranged to bring the same order to our world as appears to exist in the rest of the cosmos. The question then arises as to how best to arrange the

stuff of nature so that it reflects the same kind of order that exists in the universe. The answer, it was assumed, was to use the scientific principles of mechanics to rearrange the stuff of nature in a way that best advanced the material self-interests of human beings. The logical conclusion to this grand new paradigm was simply this: The more material well-being we amass, the more ordered the world must be getting. Progress, then, is the amassing of greater and greater material abundance, which is assumed to result in an ever more ordered world. Science and technology are the tools for getting the job done. This, in a nutshell, is the chief operating assumption of the mechanical world paradigm".

This is the world view that underpins the free enterprise, laissez-faire, competitive market philosophy. Unfortunately, we have allowed a faith in the viability of such a philosophy to become deeply engrained in our thinking (Winch 1977, p. 8). In good part, such faith reflects the way in which we are conditioned to see the world. It is an obvious fact that our society has become extremely econocentric; the economic process is exalted above all other things. Because we have been largely conditioned to think about happiness and the quality-of-life in purely materialistic terms, such a view is not easily discarded. Moreover, men's intellects are not as strong as their wills and they generally believe what they want to believe, particularly if it is some belief they associate closely with themselves and their position among other men. It is therefore not surprising that despite the general economic and ecological malaise that is persistently and cumulatively eating away at the world, most contemporary pronouncements still reflect the myth that with a little tinkering the autonomous market mechanism will protect mankind from such malaise. The economics profession, in general, largely contributes to this state-of-affairs, when, as the symptoms of the crisis become increasingly obvious, they redouble their efforts at refining their imaginary abstraction. Or worse, some create new

abstractions, equally imaginary, exalting the virtues of market capitalism, and claiming that it will lead us out of the desert, if only the state will stop interfering.

It truly appears, as Stanfield (1979) so convincingly argues, that mainstream economic science is in extraordinary crisis. By persistently failing to explain, predict or resolve such matters of pressing practicality as stagflation, resource depletion and ecological decay, the theories of economic science have, for the most part, become operationally idle. In his Presidential Address to the 1980 Canadian Economics Association annual meeting, T. Matuszewski referred to the present situation as "the poverty of economics". More fundamentally, Nicholas Georgescu-Roegen's monumental work, The Entropy Law and the Economic Process virtually demolishes the foundations upon which modern economic theory rests. Apparently, as E.F. Shumacher, author of Small is Beautiful charged, the economics profession at large is still content with contemplating the optimum arrangement of deck chairs on the Titanic while the iceberg of the Western industrial path looms near the bow (Stanfield 1979, p. 35). Georgescu-Roegen's challenge has been virtually ignored. Of course, there has long been a dissenting tradition in economics. Unfortunately, the sociology of the economics profession does not, in general, encourage its students to discover it, nor is it brought to the level of general debate.

For the purpose of illuminating the issues at hand, and for practical reasons of space, a substantive discussion of the crisis of economic science is neither necessary nor possible. Fortunately, the most

profound aspects of this crisis are perhaps the simplest to understand. Being erected as a sister science of mechanics, standard theory succeeded in turning all of nature into simple matter in motion. All the qualities of life were separated and eliminated from the quantities of which they are a part. Thus began the alienation of man from nature, since the world was now viewed as being organized in such a way that people and nature are totally separated. Ultimately, the formalism of economics eliminated people altogether, and even assumed away the economic problem of sufficient real income itself (Georgescu-Roegen 1976, p. xii; 1971, p. 343). It seems most absurd that a science of man going about his daily life process could operate without man, nature, and life itself. We must therefore wake up to the brutal truth that to be armed with a model of reality that, among other things, claims: (a) that man is separate from nature and has absolute dominion over it; (b) that totally ignores the evolutionary nature of the economic process and the irrevocable irreversibility that dominates it; and (c) omits the role of natural resources, is not to be armed at all. Simply put, to continue to act on the basis of this model is to invite disaster.

It should be observably clear then that the mechanical world view and the economic theory and prescriptions based on it cannot solve the growing crisis facing the world. In his modern classic, The Structure of Scientific Revolutions, Thomas S. Kuhn laid out a process of scientific disciplinary change induced by world views or paradigms that no longer provide sufficiently workable theories and techniques for the solution of unsolved problems. Such change is often precipitated by extraordinary science. In turn, such science finds its most fertile ground in an

environment of open, intellectual inquiry, free of the conditioned reflex of culturally based indoctrination. The astonishing faith in the ability of the market mechanism to take care of any impending economic or ecological crisis is just such a conditioned reflex. However, as daily discoveries about the world around us seem to directly contradict this understanding, the transition from crisis to extraordinary science is accelerated. The emerging synthesis of economics and other social sciences into biology and ecology is one important manifestation of this extraordinary science.

The idea that the economic process is not a mechanical analogue but more akin to an ecological system in which man's activities are subject to the overriding laws of thermodynamics owes its inception and subsequent elaboration and refinement to Nicholas Georgescu-Roegen. Building on this intellectual foundation, Jeremy Rifkin (1980) provides further insights and factually based examples in a provocative synthesis describing present day actuality. From a different perspective, Stanfield (1979) describes the utter failure of standard economics to deal with contemporary problems. His well articulated appreciation for the evolving, organic nature of society is analagous to the general themes of Georgescu-Roegen and Rifkin. In his recent development of a general theory of the thermodynamic origin of ecosystems, Lionel Johnson (1981), provides a conceptual synthesis with potentially far reaching ramifications and applicability to man-made environments. The extent of its ultimate truth content is enhanced significantly by the many and diverse ways that it meshes with the work of the other noted authors.

In view of these works and others, one is immediately struck by the utter futility and arrogance of the idea that man and nature are separate; or more specifically, that man's economic activity is somehow separate from and independent of its environment and the natural laws thereof. At bottom, this Western cultural myth is another manifestation of the dogma of standard economics and the culturally propagated blind faith that self-perpetuates that dogma. The idea that man, as a biological organism, could possibly be separate from nature, the fount of all life, is ridiculous. In actual fact, broadly interpreted the economic process is a continuation of man's biological one. With this firmly established, blind trust in the myth of man's omnipotence might prove to have negative survival value. Like all living organisms, man is totally dependent on his ability to exploit the environment for the matter-energy necessary to sustain existence. To a very large extent, however, man has used science and technology to enhance his exploitation in ways far beyond the capabilities he is born with. Such technology has become so complex, expansive and all-pervasive that we have come to believe that come what may, technology will find a way. We pride ourselves on being a technological society using technology to solve problems. In fact, technology has been so overpraised and oversold that many believe in the myth that such industrial artifacts actually free us from dependence on the environment. Nothing could be further from the truth. Stripped of all the mystique that surrounds it, technology does nothing more than transform matter-energy from nature into the many forms used to maintain the human cultural systems. The idea that such technological transformations are somehow free of any and all laws and limitations governing such transformations in the rest of creation reflects

only arrogance and folly. It is an incontrovertible fact that, like everything else in nature, every physical and material activity of man is under the supreme reign of the laws of thermodynamics. These laws provide the overarching scientific frame for the unfolding of all physical activity in this world (Rifkin, 1980).

Simply put, the first law states that in a closed system, like earth, the amount of matter-energy available in a form that can be used by life bearing structures, including man, is constant. In high school terminology, it states that all matter-energy on earth is constant, that it cannot be created or destroyed, only changed in form but not in essence. The second law, or the Entropy Law, essentially states that this available matter-energy undergoes a continuous, and irrevocable degradation into an unavailable state. In more familiar terms, matter-energy can only be changed in one direction, from available to unavailable, or from usable to unusable, or from ordered to disordered. Entropy then is an index of the relative level of unavailable matter-energy, and it continuously increases to a maximum. Put another way, entropy is a measure of the amount of matter-energy no longer capable of conversion into work. Low entropy therefore corresponds to available or accessible matter-energy and high entropy to the opposite. The dissipation of matter-energy goes on automatically everywhere. Every living organism maintains its own level of entropy or ordered structure by exploiting the environment for low entropy, even though each individual organism ultimately succumbs to the Entropy Law.

Given that all biological life feeds on low entropy, the connection between low entropy and economic value should be obvious. From this point we get some glimmering of the fallacy that value is measured by prices and money. In reality, cost and scarcity consist in essence of low entropy, not money, and are subject to the limitations imposed by natural laws. Further, it should be equally obvious that man's whole economic life feeds on low entropy. In this regard, however, there are some critical differences between the entropic nature of man's activities and that of other living organisms.

In natural systems, individual organisms and groups of like individuals interacting equally within the boundaries of their niche are genetically programmed to both actively acquire and actively conserve energy. Given certain conditions, generally applicable, the group of like individuals functions as an egalitarian, organized, coherent group in order to achieve a common goal, which is a unique state of least entropy production. (Johnson, 1981). In other words, such individuals and their groupings tend to minimize the rate of energy flow consistent with maintaining existence. The goal of the individual is considered secondary to the goal of the group, however, the group goal is simply the mean of the individuals. This is referred to as the mediocrity trap. This enforced equality at least entropy production supports cohesion within the group.

On the other hand, the biosystem as a whole, and its component ecosystems or points of overlap of a number of individual niches, have a natural tendency to proceed to a state of maximum entropy and maximum

entropy production rate. All such entropic processes go on automatically, by themselves, in response to fluctuations in energy availability, the primary source of which is the flow of solar energy (Johnson, 1981).

In human systems, the economic process is not automatic but dependent on the purposive activity of human individuals. In addition, the philosophical rationale of such activity in our culture stresses the active acquisition of low entropy and the maximization of energy flow, entropy and entropy production rate at all of the individual, group, and system wide perspectives. Conservation is not actively pursued as a general form of behaviour except perhaps in times when acquisition proves difficult and even then is a limited response. Egalitarian goals, if they exist, are relegated to the institutions of the state and are subject to the vagaries of political philosophy. Of most significant importance is the principle source of man's low entropy as compared to that of other organisms. While every living thing, including man, owes its ultimate existence to the flow of energy from the sun, man alone has increasingly coupled his existential lot to the extraction of matter and energy stored in the earth's crust. In fact, in every aspect of man's economic life he has increasingly substituted scarce, non-renewable matter-energy of terrestrial origin for the essentially unlimited solar flow.

The taproot of economic scarcity, resource depletion and pollution in their many manifestations, as evidenced by contemporary economic and ecological crises, should therefore become increasingly transparent. Natural ecosystems are driven by solar energy input, the amount of which

will continue at the same intensity (practically) for the next few billion years, and the use of which is pollution free. The entropic nature of natural systems transforms low entropy into biomatter and dissipated heat (as can be illustrated by the use of a biotic pyramid or food chain). This goes on in an effectively self-limiting, automatic way, subject to the checks and balances of natural laws. This contrasts with man-made ecosystems which are driven primarily by the relatively and absolutely meager stock of accessible terrestrial matter-energy. The material side of man's economic process transforms low entropy into some biomatter, himself, but overwhelmingly, the product of the economic process is irrevocable waste. The faster the process goes, the faster the waste accumulates. As technological change, which reflects nothing more than the increasing diversity and evolution of "species" of man-made transformers of matter-energy, brings us "more and bigger and better" material goods, it also brings "more and bigger and better" waste. Such technological change (*ceterus paribus*) requires increased energy flows and entropy production because the energetic costs associated with diversity, energy dispersal, evolution and complexity are all operational in man-made ecosystems. Furthermore, the checks and balances inherent in the automaticity of natural processes are largely absent from human systems. The notion that unlimited economic growth is not only possible but the only natural and desirable goal of a "rational" society was and still is the proud claim of standard economic science and philosophy. Beyond the institutions of law and politics, our cultural philosophy believes that there is no need for purposive limits on man's economic process because there are no absolute limits to that process beyond man's control. It appears that it still has not sunk in that such a view is completely counter

to the real workings of the world. As a result, our culture continues to condition us to think of the economic process as somehow possessing the power to defeat the laws of elementary matter. But as they say, just because a majority of people believe something to be true does not make it so. Such ideological tenacity notwithstanding, these laws do govern all physical activity in the world, and as such provide a good measure of understanding of certain of our problems.

Economic scarcity is a hard fact of life because the amount of low entropy, or accessible matter-energy, in our surrounding environment decreases continuously and irrevocably, and because we can use a given amount of it only once. These are observable facts. There are no everlasting material structures; all around us there is wear and tear, oxidation, chipping, blowing and washing away. Topsoil everywhere is washed out into creeks, rivers, lakes and the ocean. Food for the table and wood for the fire must be constantly replenished.

Resource depletion is the inevitable consequence of a system that maximizes entropy and matter-energy flow out of a source that is an essentially fixed stock. Such behaviour is tantamount to treating a bank account balance like income. Such maximization behaviour at the natural ecosystem level is reasonable and sustainable only because the driving solar energy input is a quasi-constant flow and virtually inexhaustible. We must come to realize that no economic system can survive without a continuous inflow of energy and matter. Industrial societies are particularly vulnerable because they are constantly, and now increasingly, confronted

with a decreasing accessibility to matter-energy. The extent to which man is even now scouring the furthest frontiers of the planet for low entropy sources provides an ominous indicator of this predicament. The claim of standard economics that the price system will protect scarce resources from complete exhaustion and take care of any ecological crisis rings hollow when closely examined. If matter-energy become scarce, the argument goes, we will constantly substitute other factors for them. But since the only other factors in the economic process are labour and capital, which are themselves only transformed matter-energy, it is difficult to see by what magic we can make more of these from less and less matter and energy (Georgescu-Roegen, 1981). Clearly, substitution cannot go on forever within a finite stock of accessible matter-energy whose irrevocable degradation is speeded up through use. Innovations that allow the more efficient use of low entropy sources may help, however, the limit to such technological progress is set by the theoretical coefficient of efficiency which, as we know from Carnot, can never be attained in actuality. Over the long term, matter-energy accessibility is determined by efficiency in terms of energy, not price or money. Frontier exploration might yield available energy, but whether any such discoveries will represent accessible energy depends on how much equivalent energy we have to use out of already accessible stores to locate, extract, process, deliver and distribute these discoveries. If we have to use as much or more than an equivalent amount then such available energy is not accessible. Based on these considerations it seems certain that a substantial part of the estimates of ultimately recoverable or hypothetical reserves do not constitute accessible energy. In any case, whatever the ultimate limits to accessibility are, there are other, more practical,

constraints that suggest there are affordability limits of equally compelling import. Based on currently observable experience, the monumental costs associated with frontier exploitation are already signalling such limits to accessibility directly related to the ability of the population to pay the price required to cover such costs. One can only wonder to what extent the population must be impoverished before these hard facts sink in. One thing is certain though, the material entropy of a closed system must ultimately reach a maximum. No imaginable price mechanism can alter the observable fact that, however defined, all kinds of accessible energy, matter and land are in finite amount. When this maximum entropy point will be reached is not possible to determine, but contemporary events suggest that it is much closer than most people would like to think.

Pollution, as we noted earlier, is an output of the economic process that is just as unavoidable as the input of natural resources. It is, let us recall, simply the dissipated matter and energy that accumulates from the economic process. Whenever matter-energy is extracted from the environment and processed through the human ecosystem, part of it becomes dissipated or wasted at every step until all of it, including the final products end up as one form of waste or another. This is an observable fact. Most profoundly, the Entropy Law tells us that every time accessible matter-energy is used up, it creates even greater disorder somewhere in the surrounding environment. The massive dissipation of matter-energy apparent in modern industrial society is creating even more massive disorder in the world we live in.

The degradation of natural ecosystems results when human ecosystems with high entropy relative to total energy effectively usurp the biotic energy of natural systems with low entropy relative to total energy. In other words, the biotic energy in natural systems is "captured" by the high entropy human system, either through excessive exploitation for biomass, or through their use as waste disposal dumps. For example, loadings of nutrients, sediments, toxic substances, acid rain, and carbon dioxide beyond the carrying capacity of impacted ecosystems can and very often do result in a demonstrable lessening in utilizable biomass. As Rifkin (1980, p. 246) points out;

"...by "hot-wiring" the flow of living matter through society's energy flow line, we deplete in absolute terms the available stock of living matter. In a literal sense, renewable resources are really non-renewable".

Standard economic thinking has conditioned us to view this degradation as nuisance causing side effects that are tolerable because the economic benefits derived are greater than the costs involved in the environmental decay. This simply isn't true because if it were, then the economic process could violate the Entropy Law. At a time when the material basis of life was relatively limited additional environmental exploitation met relatively well defined and objective needs. We have, however, moved a long way away from the low economic surplus of early industrialization to the generally high surplus of today. By focussing exclusively on money and related flows, and totally ignoring the role of natural resources and the entropic nature of the economic process, standard economic thinking views this material transition as progress. For every other living

organism, progress has been related to the broadening of the environmental conditions in which a species can exist, while still maintaining a state of non-specialization (Johnson 1981, p. 587). Put another way, that which furthers the survival and development of the species is progressive (Stanfield 1979, p. 49). By these biological criteria standard economic thinking once again reveals its upside-down relationship to the reality of nature. By maximizing energy flow and entropy production, man's material activities are actually lowering the carrying capacity of the biosphere for all forms of life, including himself. By raising the entropy level of the surrounding environment man accelerates the normal degradation of all material macrostructures (including life forms) whose entropy is lower than its surroundings (Georgescu-Roegen 1976, p. 12; Johnson 1981, p. 584). As a general principle, higher entropy leads to higher stress, which, in turn, leads to higher energy expenditure. Completing the vicious circle, this leads to higher entropy and the process repeats itself. The stress level on the human component alone is exacting a colossal toll as evidenced by the alarming statistics on mental health, environmental and stress related mortality and morbidity and general social malaise. It appears that even man-made environments, for whose continued growth we seem willing to degrade the entire biosphere, do not necessarily provide a fit place for man's biology to exist. And therein lies the rub. As an integral part of nature, man cannot possibly escape the entropic degradation that his own activities cause. Every time man makes a part of the biosphere less fit for the organisms that inhabit it, he also makes it less fit for himself.

VII IMPLICATIONS FOR PHOSPHORUS MANAGEMENT:

The implications of the above arguments for phosphorus management are straightforward. If we understand the problem well, there are a number of themes that must be pursued in the development of management plans. First, while most people refuse to accept it, the economic and ecological crises of today are clear precursors of the coming end of fossil fuel, non-renewable resource based economic systems. We can therefore ill afford to lose the basic biotic energy of the Great Lakes ecosystem. Second, we must take a long-term perspective as regards both the structure of individual programs, and the source of the problem. Third, we must recognize the existence of absolute limits and the finite nature of both terrestrial, matter-energy resources and the capacity of living systems. Fourth, we must take an ecosystem approach and consider all aspects of the problem. This will involve examining areas and issues that entail overlapping institutional responsibility, but it is absolutely necessary to examine the whole if meaningful understanding and effective long-term solutions are to emerge. Finally, we must throw off the mental shackles of culturally indoctrinated economic thinking. The dangers inherent in the uncritical acceptance of the maximizing principles of standard economics should be clear to all but the ecologically blind. The most rational conduct is to minimize regrets, and to avoid overuse of resources, rather than achieving some unmeasurable and unknowable optimum use. In other words, we should be mainly interested in protecting ourselves against serious losses of living systems; losses that defy quantitative measurement.

From this perspective, present policies and a general outline of possible future strategies can be considered. The number one policy goal should be to minimize the unnecessary use of phosphorus and related compounds. It must be recognized that phosphorus is a highly critical and non-substitutable element in biological processes and exists in a finite amount that is in very small supply in the environment. The United States General Accounting Office (1979) reported their concern that over the next two decades the richest U.S. phosphate deposits are likely to be depleted. Alternate sources on a large enough scale are featured mainly by big question marks. Skyrocketing price increases for all forms of fertilizers are primary indicators of accessibility limits combined with rising fossil fuel costs and enormous increases in demand. In addition, the modes in which phosphorus participates in both natural and man-conducted processes are highly dissipative so recycling is difficult. Furthermore, the Entropy Law tells us that physical control is easier (and therefore cheaper) at the point of lower entropy, which corresponds to the resource use end rather than the pollution end. Therefore, quantitative restrictions on the phosphate content in detergents, or other products, are the easiest and most effective measures for the obvious reason that the throughput of nutrients is cut back at its source. Considering that our very recent ancestors and many contemporary cultures beat their clothes clean down at the river, the clamour over the minimal impacts of detergent phosphate limitations seems a little hollow.

Phosphorus removal at sewage treatment plants is a practical measure given the reality of our social infrastructure and technological bent. It is, however, tied to a complex and centralized system that is becoming increasingly expensive and sometimes prone to problems. From a long-term perspective such issues as sludge disposal, toxic contaminated sludge, and increasing costs associated with the entire human waste removal and treatment process are likely to become increasingly significant. From a phosphorus perspective, we are running into a diminishing returns situation since as the percentage of phosphorus removal increases, the cost increases even more steeply. In addition, some evidence exists that the technology is not being used to its full potential because of improperly or inadequately trained operating staff. It would seem advisable that such effectiveness losses be thoroughly exploited and rectified before expenditures on further complexity are introduced to achieve any additional effluent concentration reductions. In this vein, it would also seem advisable that across the board measures be replaced or modified by a plant by plant scheme to ring out the maximum potential for effort expended. On the other hand, it is important to remember that the biological availability of waste treatment plant effluent phosphorus is in the range of 60-80 percent. This compares with tributary sources that range from 20 to 40 percent available. It would thus appear appropriate at this time to shift some of the remedial program focus away from considerations based mainly on total phosphorus towards approaches that take bio-availability into account. At a recent workshop on Lake Erie Oxygen Depletion (National Water Research Institute,

Burlington, December 2 and 3, 1981) it was suggested that effluent outfalls be extended beyond the littoral zone in order to minimize nearshore effects of large doses of bio-available phosphorus.

In view of our earlier discussions, a strong argument can be made that diffuse source remedial measures entail ramifications far beyond purely nutrient related issues. Recent events have provided stark evidence that agriculture, in general, is in very serious economic trouble. Perhaps this concern will remove the blinkers that have caused a general failure to appreciate the accumulating and convincing evidence, cited earlier, that present agricultural methods and policies are on a collision course with disaster. Modern agricultural technique, featuring as it does a massive substitution of sophisticated machinery and petrochemicals for the traditional methods involving man, animals, manuring, crop rotation and natural pest control represents probably the single most significant and dangerous squandering of terrestrial matter-energy ever devised, next perhaps only to the nuclear arms race. It is dangerous because too many people think that food comes from the store. It is this popular delusion that causes many of us to lose sight of the fact that all activities of man are tributary to agriculture and mining. Despite the obvious truism that man must satisfy his biological needs before he can pay attention to any others, we still seem to ignore, or even deny, the priority that the production of food must have over the production of other goods. In our haste to embrace every consumer gadget that comes down the pipe we have lost sight of the specific causal order that relates the various activities of the economic process. The apparent cornucopia of modern agriculture, which

even now is proving to have limits as yield increases approach asymptotic peaks, has only been made possible by the constant injection of massive and more than proportional doses of highly concentrated synthetic fossil fuel energy. Because of strongly decreasing returns present farming technology is caught in a vicious spiral of greater energy infusions, faltering incremental yields, and increasing losses in the form of soil fertility, soil erosion and pest resistance. The seriousness of these problems seems to be underrated consistently.

In the face of this clear and present danger, we are truly blind if we believe that it might somehow be "socially unacceptable" to mount a concerted and meaningful effort to staunch the irrevocable, haemorrhagic loss of topsoil and the food production capability that goes with it. By what form of thinking does the alternative, a continued, long-term depletion of the very bottom layer of the terrestrial food chain that sustains our existence, become socially acceptable? If we are so enslaved to the market ideology and the money fetish that dominates it that we have lost touch with our own existential reality, then we will truly suffer when the bitter night sets in. Given that: (a) there is no substitute for the living ecosystem we call soil; (b) major declines in crop yields are inevitable sooner or later where soil loss is greater than accretions; (c) soil erosion in prime agricultural areas of the Great Lakes basin is excessive enough to reduce the productivity potential of affected cropland; (d) present agricultural methods cannot for long continue to make up for such losses and in any case are major contributors to the problem; (e) any form of agriculture, being governed by the Entropy Law, constantly depletes the soil and lowers

production through a constant process of taking off more than is put back, and; (f) present agricultural practice will fail when the fossil fuel energy subsidy is removed or attenuated, indications of which are already being felt, there appears to be a prima facie case for a fundamental and broad-based change in our present food supply system. Adding to this litany the pollution problems caused by phosphorus and nitrogen related phenomena, pesticide residues and related potential, and the various arguments that rank suspended sediments as an equal or worse water quality problem (at least in Lake Erie; Taft and Kishler, 1973), the rationale for sweeping remedial programs to deal with non-point source loadings seems self-evident. As noted earlier, a great deal of work has already been done to identify effective remedial measures. What might be helpful in furthering the awakening of awareness relative to these issues is an integration of all aspects of the food supply problem along the lines outlined here and dealt with partially elsewhere. The recent report of the Ontario Energy and Agriculture Policy Committee, entitled, Energy and Agriculture, underscores the emerging awareness of the need for change. This would appear to be a particularly efficacious opportunity to contribute to the solution of a pressing problem with manifold implications far beyond the issue of water quality.

CONCLUSION:

The melding of economics into ecology and biology reveals, at the very least, that man is, in fact, only one member of a biotic team, a team that encompasses all of creation. The actualization of this revelation in

our relationship to the environment that sustains us will require the rethinking of many ideas that we take for granted, and a goodly dose of self-inquiry. Aldo Leopold (1966 p. 238-246) fully anticipated the essential nature of the problem and the eventuality that it would someday have to be confronted head-on;

"There is as yet no ethic dealing with man's relation to land and to the animals and plants which grow upon it.... The land-relation is still strictly economic, entailing privileges but not obligations....Obligations have no meaning without conscience, and the problem we face is the extension of the social conscience from people to land.

No important change in ethics was ever accomplished without an internal change in our intellectual emphasis, loyalties, affections, and convictions. The proof that conservation has not yet touched these foundations of conduct lies in the fact that philosophy and religion have not yet heard of it. In our attempt to make conservation easy, we have made it trivial".

The maximizing principles of standard economics, taken alone, are the product of an ideologically based philosophy with a pronounced dogmatic and pragmatist bent. There are no ethical choices to be made and no absolutes to be taken account of. These principles reduce the essential object of economics to that of allocating given means towards the optimal satisfaction of given ends. Although the value and economic nature of this approach cannot be denied, it provides only a very limited view and understanding of the totality of the economic process. Unfortunately, the static, ahistorical and mechanical essence of these principles simply cannot deal with the evolutionary reality of the economic process and the environment to which it is essentially grafted. In fact, new economic means, new economic ends and new economic relations are continually created at an evolutionary

pace far too rapid to allow any mechanical analogue to capture a relevant picture of the economic reality.

The challenge then is to recognize that the fundamental principles of standard economics are not universally valid, but reflect the institutional traits of a capitalist society. There is nothing wrong with that as long as we always remember that society is not an immutable entity, but evolves continuously in endless forms that differ with time and place as well (Georgescu-Roegen 1971, p. 318-330). The sin of standard economics is its denial of the necessity to pay attention to these evolutionary aspects of the economic process, its surrounding environment, and society and culture. It is therefore obliged to practice the dogma that its principles are valid everywhere, and at all times. The dangers involved in continuing to foster and practice a blind faith in all aspects of such a view should be increasingly obvious. In particular, such faith discourages rational inquiry and the unrestricted use of man's unique capacity for conscious foresight - the capacity to simulate the future in imagination (Dawkins 1976, p. 214-215). It was man's intelligence that created the problems we face and only a full and creative use of that faculty, the tool Nature provided for our survival, will solve them.

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CA1 EP 75081Q72

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QUALITY, ECONOMICS AND ENTROPY: PHOSPHORUS MAN
LAKE ERIE. / Muir, Tom. 1981.

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